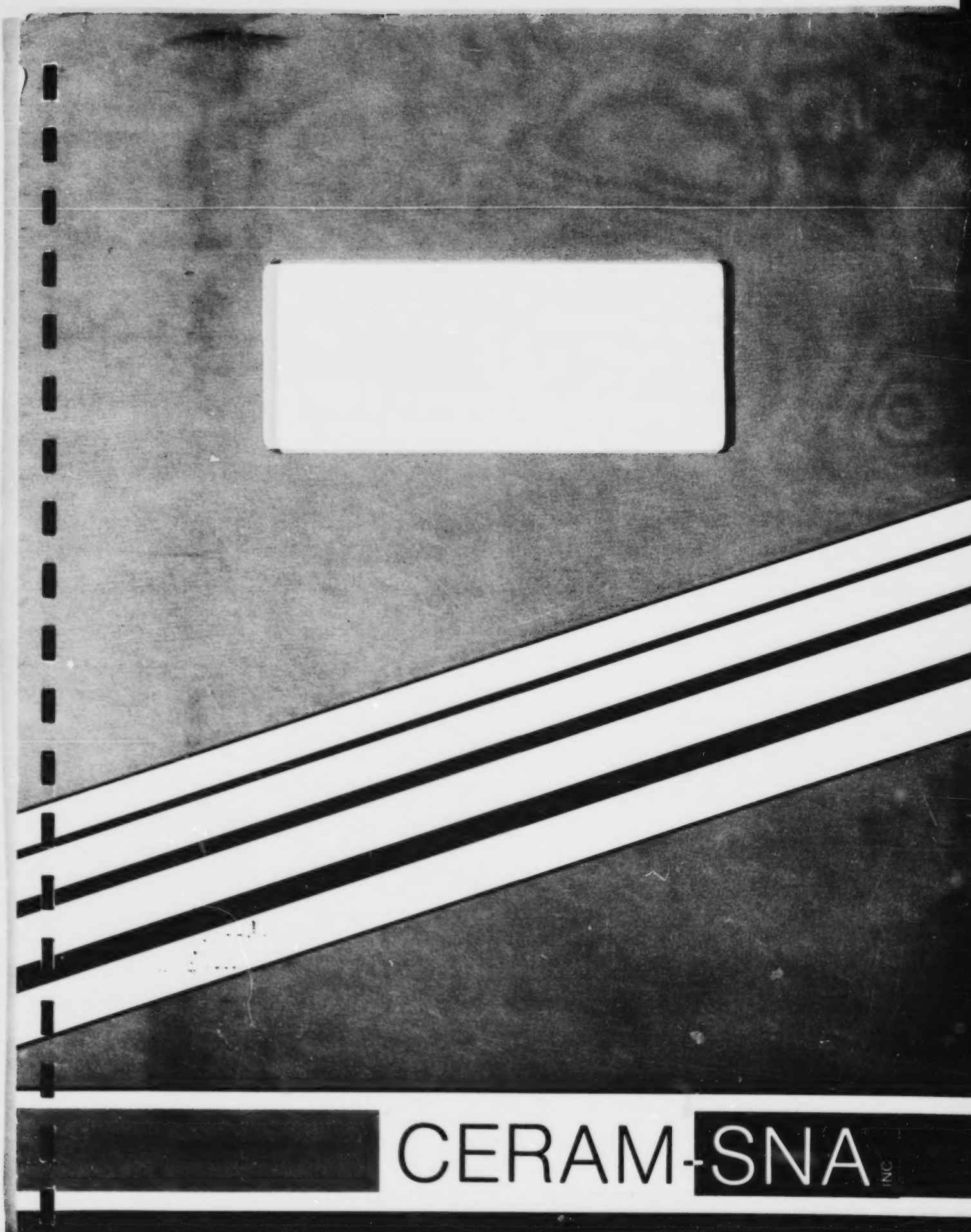
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SIXTEENTH PROGRESS REPORT
CONTRACT TO DEVELOP AN ASBESTOS CEMENT (A/C) COOLING TOWER FILL FOR THERMAL GENERATING PLANTS

Contract serial number OSQ84-00391

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Report no. 23

to:

J.-G. Fradette, President, Atlas Building Materials inc.
a division of Atlas Turner inc.

from:

M. Cossette, directeur, recherche technologique
Responsible for execution of this contract
Sherbrooke Research Center

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SIXTEENTH PROGRESS REPORT

CONTRACT TO DEVELOP AN ASBESTOS-CEMENT (A-C) COOLING TOWER FILL FOR THERMAL GENERATING PLANTS

(a) SUMMARY OF WORK ACCOMPLISHED DURING THE REPORT PERIOD.

(A-1) May 1987

. Flexural testing:

The flexural modulus of rupture after 28 days of curing, either in saturated air or by immersion in water, was carried out. The results are presented in Annex 1 to 8, as follows:

ANNEX	FIBRE LENGTH	FIBRE CONTENT	FIBERIZATION
1 and 5	low (7D700)	high (20%)	low (56 dm^2/g)
2 and 6	low (7D700)	low (10%)	high (117 dm^2/g)
3 and 7	high (4T500)	low (10%)	low (53 dm^2/g)
4 and 8	high (4T500)	high (20%)	high (117 dm^2/g)

In general, the Hamilton slag gave a flexural modulus of rupture averaging 6.3% higher than the Algoma slag while the basis for comparison (the type 50 cement products) averaged 5.4% lower.

In the case of the type 50 cement products, the immersion cure gave results some 15% higher than steam box curing.

. Exposure to aggressive waters:

None of the specimens showed any signs of deterioration

. Freeze-thaw testing:

None of the specimens showed any signs of deterioration.

. Exposure to aggressive waters followed by exposure to freezing and thawing: series 701.2.2 showed slight spalling after three cycles of exposure.

. Exposure to aggressive waters followed by exposure to moisture shocks: series 701.2.2 showed spalling after two cycles.

A-2 June 1987

. Exposure to aggressive waters:

The trials were finished after six weekly cycles and the results are pre-

sented in Annex 9 and 12. In sea water the Algoma slag products were resistant to visible deterioration in 3 cases out of 4 whereas the type 50 cement products were resistant to visible deterioration in only 1 case out of 4. In the sulfated water the Algoma slag products resisted visible deterioration in every case whereas the type 50 cement products resisted in only 1 out of 4 cases. It may be concluded that the Algoma slag products are apparently more resistant than the type 50 cement products.

- Exposure to aggressive waters followed by exposure to freezing and thawing:

  The trials were finished after six weekly cycles of exposure and the results are presented in Annex 10 and 12. The sea water exposures caused slight spalling or moderate spalling in every case for type 50 cement products whereas the Algoma slag products suffered only slight spalling in half the cases. The sulfated water exposure caused slight spalling in 1 out of 4 cases for type 50 cement products whereas all the Algoma slag products resisted visible deterioration. It is concluded that the Algoma slag products are apparently more resistant than the type 50 cement products.

- Exposure to aggressive waters followed by exposure to moisture shocks:

  The trials were finished after six weekly cycles of exposure and the results are presented in Annex 11 and 12. The sea water exposures caused slight to moderate spalling in every case with the type 50 cement products whereas the Algoma slag products gave only 1 out of 4 cases of visible deterioration (incipient delamination). The sulfated water exposure caused no deterioration for half the type 50 cement products while the other half suffered slight spalling or delamination. The Algoma slag products did not resist as well and all suffered either incipient delamination or moderate spalling. It is concluded that the Algoma slag is superior to the type 50 cement products for apparent resistance to sea water whereas the opposite is true for sulfated water.

- Freeze-thaw trials

  The trials with the slag products were finished after 100 cycles. The trials with the type 50 cement products are not finished and had reached only 74 cycles. Preliminary observations (not final) are presented in Annex 13. It may be observed that the Algoma slag products were apparently unaffected in 6 out of 8 cases whereas the type 50 cement products were still unaffected after 74 cycles in only half the cases. It is concluded that the Algoma slag products are more resistant to freezing and thawing than the type 50 cement products.

- Harkort trials

  The trials were carried out according to the following temperature

schedule. Between 100 and 200°C the temperature was increased in 20°C increments and between 200 and 280°C the increments were of 10°C. The appearance of the test specimens is described in Annex 14 and 15. The products that gave the best resistance were coded 502, 609 and 806 and these include one type 50 cement and two Algoma slag products. However all of the latter were pressed products and free of air entraining agents. Two of the Algoma slag products showed incipient spalling but none showed any actual spalling whereas half of the type 50 cement products showed incipient spalling including 3 out of 8 that were actually spalled. It is concluded that the Algoma Slag products showed superior resistance to the Harkort test that combines very severe temperature and moisture shocks.

A-3 July 1987

. Flexural testing of products exposed to aggressive waters

The results obtained before exposure are presented in Annex 16, 17 and 18. Annex 16 shows that when the two slags are compared on the basis of curing in saturated air, results before exposure are not significantly different for products with binders composed of type 50 cement, Algoma slag, or Hamilton slag. Annex 17 shows that when the two slags are compared on different bases with saturated air curing for Hamilton slag products and immersion curing for Algoma slag products, the results are not significantly different.

When the probability contrast sums are ranked as in Annex 19 and 20, it becomes apparent that in general, the contrast sums differ by an average of only two ranks between the Algoma and Hamilton slags. Parameter X14 designates the binder type and the substantial rank differences between Algoma and Hamilton slag products indicates that the various inter-effects (synergisms) with the other parameter are substantitally more significant for the Algoma slag binder. The large difference in the rankings for parameter X4 (fibre content) remains unexplained.

The parameters for which the contrast sums are 10% lower than the highest contrast sums are as follows:

RANK	ALGOMA	HAMILTON
1	X6 Fiberization	X8 Silica fume
2	X12 Air entrainment	X14 Binder
3	X8 Silica fume	
4	X14 Binder	

The contrast sum for the degree of fiberization is negative and this indicates that the fibres that are least fiberized yield greater white water concentrations.

ETUDE DU LAITIER D'ALGOMA STEEL

PROBABILITE vs PERTE DE MATERIAUX FINS

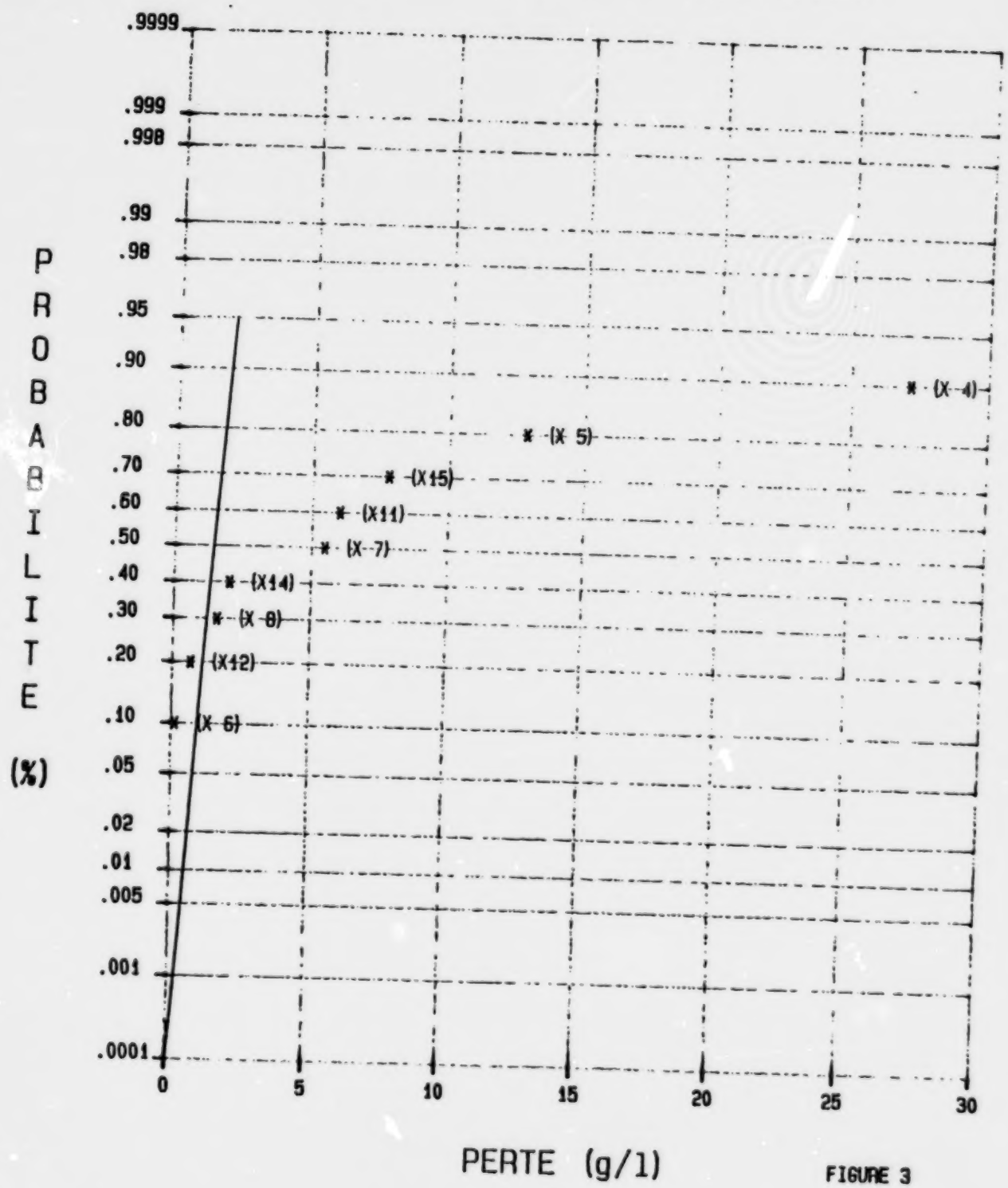


FIGURE 3

ETUDE DU LAITIER DE HAMILTON

PROBABILITE vs PERTE DE MATERIAUX FINS

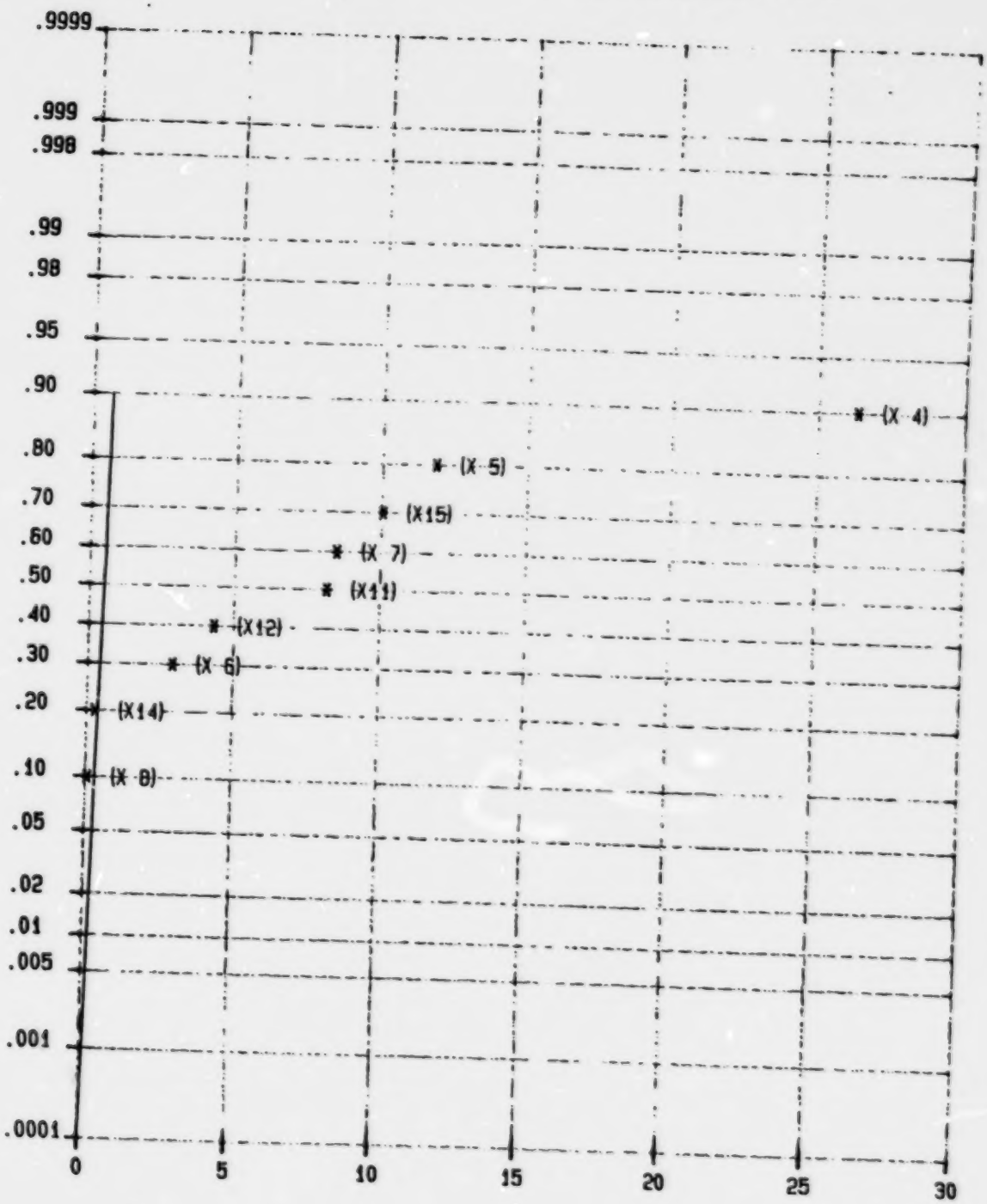


FIGURE 4

Fig. 3 and 4 illustrate the probabilities as a function of white water concentration. The parameters that had the greatest influence (above 20% of the highest value) on the white water concentration were, in decreasing order of importance:

RANK	ALGOMA	HAMILTON
11	X5 Fibre length	X5 Fibre length
10	X9 Pressing	X9 Pressing
9	X7 Fly ash	X7 Fly ash
8	X14 Binder	
7	X1 Curing	
6	X11 Superplasticizer	
5	X15 Dispersant	

The results obtained after exposure to aggressive waters are presented in Annex 21, 22 and 23. Annex 21 for saturated air cured products only, after exposure to aggressive waters, shows that Algoma slag gave 3% higher strength than type 50 cement, Hamilton slag gave 7% higher strength than type 50 cement, and 14% higher than Algoma slag, on average. Annex 22 compares Algoma slag products cured by immersion against Hamilton slag products cured in a steam box, and this shows that the Algoma slag products are 6% stronger than the type 50 cement products while the Hamilton slag products are 20% stronger than the type 50 cement products. If no account is taken of the differences in curing mode, the Hamilton products are 7% stronger than the Algoma products. Since the differences in flexural strength were not significant before the exposure to the aggressive waters it is concluded that the Hamilton slag products displayed superior resistance to this aggression.

Annex 23 shows the results obtained with sea water and sulfated water exposure of products cured in saturated air or by immersion. These results are summarized hereunder in decreasing order of flexural strength after exposure.

BINDER	STUDY	CURING	WATERS	MODULI, MPa
Hamilton slag	Hamilton	both	sulfated	53
Algoma slag	Algoma	both	sulfated	46
Hamilton & 50	Hamilton	both	both	45
Hamilton slag	Hamilton	both	both	44
Algoma & 50	Algoma	both	both	42
Hamilton & 50	Hamilton	both	both	42
Type 50 cement	Hamilton	both	sea	41
Type 50 cement	Algoma	both	sea	40
Algoma Slag	Algoma	both	both	40
Type 50 cement	Hamilton	both	both	39
Algoma & 50	Algoma	both	both	39
Type 50 cement	Algoma	both	both	38

BINDER	STUDY	CURING	WATERS	MODULI, MPa
Type 50 cement	Algoma	both	sulfated	37
Type 50 cement	Hamilton	both	sulfated	37
Type 50 cement	Algoma	both	sea	37
Hamilton slag	Hamilton	both	sea	36
Algoma slag	Algoma	both	sea	34

It may be concluded that after exposure to sea water, the Algoma slag products were weaker than the type 50 cement products by an average of 15% and the comparable number for Hamilton slag products is 12%. After exposure to sulfated water the Algoma slag products were 35% stronger than the type 50 cement products and the comparable number for Hamilton slag products is 43%. It is concluded that the Hamilton slag was superior to the Algoma slag and both slags were superior to the type 50 cement, for sulfated water exposure.

The contrast sum rankings are presented in Annex 24, and these show that the parameters that had the greatest influence on the flexural strength after exposure to the aggressive waters were the following, in decreasing order of importance:

RANK	ALGOMA STUDY	HAMILTON STUDY
13	--	X5 Fibre length
12	X5 Fibre length	X4 Fibre content
11	X4 Fibre content	X11 Superplasticizer
10	X8 Silica fume	X15 Dispersant
9	X1 Curing	X2 Aggressive water
8	X2 Aggressive water	X14 Binder

Fig. 7 and 8 shows plots of flexural resistance as a function of probability for Algoma and Hamilton slag products respectively. These show that the following parameters had negligeable effects.

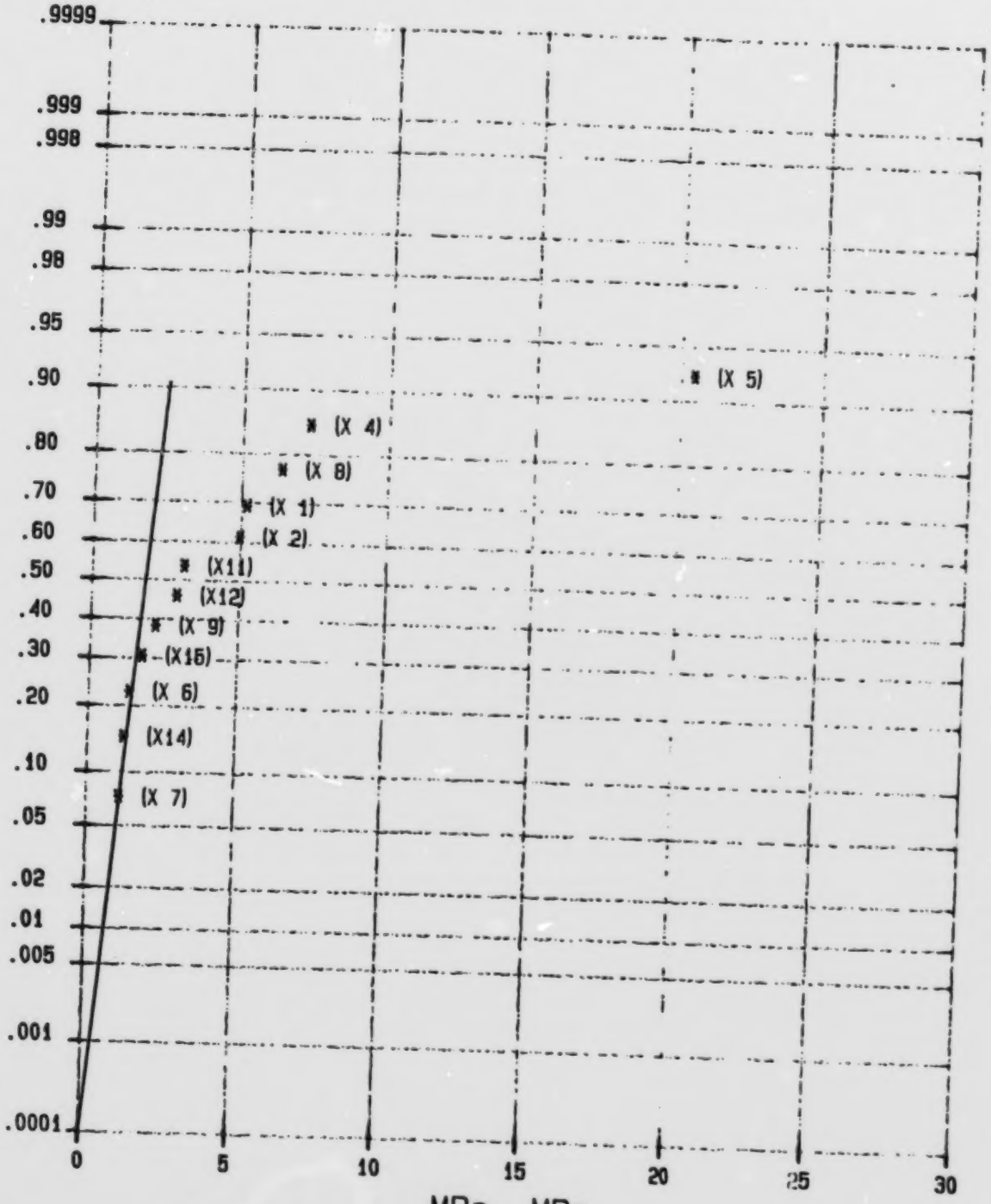
RANK	ALGOMA STUDY	HAMILTON STUDY
1	X7 Fly ash	X1 Curing
2	X14 Binder	X12 Air entrainment
3	X6 Fiberization	
4	X15 Dispersant	

Annex 25 presents the comparison between flexural moduli before and after exposure in tabular form.

Annex 26, presents the contrast sums for both slags applicable to the differences obtained between the type 50 cement and slag products for each trial.

ETUDE DU LAITIER D'ALGOMA STEEL

PROBABILITE vs RESISTANCE EN FLEXION

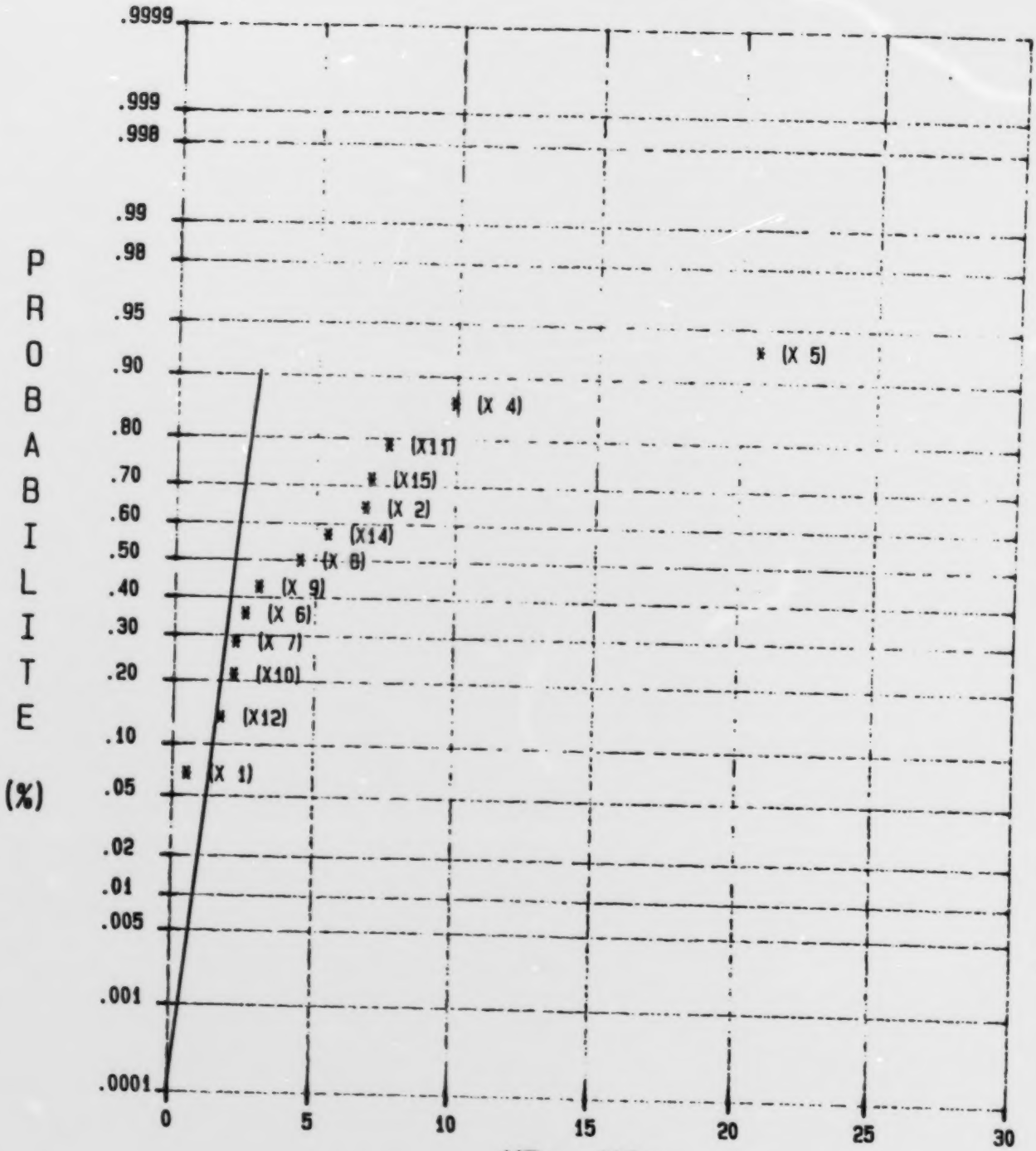


APRES EXPOSITION AUX EAUX AGRESSIVES

FIGURE 7

ETUDE DU LAITIER DE HAMILTON

PROBABILITE vs RESISTANCE EN FLEXION



APRES EXPOSITION AUX EAUX AGRESSIVES

FIGURE 8

The parameters that had the greatest influence in distinguishing each slag from the comparable type 50 cement products were the following, in decreasing order of importance:

RANK	ALGOMA STUDY	HAMILTON STUDY
13	--	X9 Pressing
12	X9 Pressing	X2 Aggressive water
11	X2 Aggressive water	X8 Silica fume
10	X7 Fly ash	X11 Superplasticizer
9	X5 Fibre length	X15 Dispersant
8	X11 Superplasticizer	X4 Fibre content

Fig. 9 and 10 show plots of increase in moduli as a function of probability for Algoma and Hamilton slag products respectively. These show the least significant parameters were:

RANK	ALGOMA STUDY	HAMILTON STUDY
1	X12 Air entrainement	X10 Type of exposure
2	X6 Fiberization	X14 Binder
3	---	X6 Fiberization

. Flexural testing of products exposed to aggressive waters followed by freezing and thawing:

The results are presented in Annex 27. For products exposed to sea water followed by freezing and thawing exposure the Algoma slag products were 16% stronger than the type 50 cement products. For products exposed to sulfated water followed by freezing and thawing exposure the Algoma slag products were 28% stronger than the type 50 cement products. If results for sea and sulfated waters are combined, then the Algoma slag products averaged 23% stronger than the type 50 cement products.

Annex 30 presents the same data together with the data for exposure to aggressive waters followed by moisture shock exposure, and data on freeze-thaw exposure alone. Annex 31 presents the losses in strength due to the various exposures. Annex 32 presents the probability ranks for the contrast sum of the adjusted flexural moduli of rupture after the various exposures. This shows that the most important parameters affecting the resistance to exposure to aggressive waters followed by freeze-thaw exposure were, in decreasing order of importance:

ETUDE DU LAITIER D'ALGOMA STEEL

PROBABILITE vs GAIN DE RESISTANCE EN FLEXION

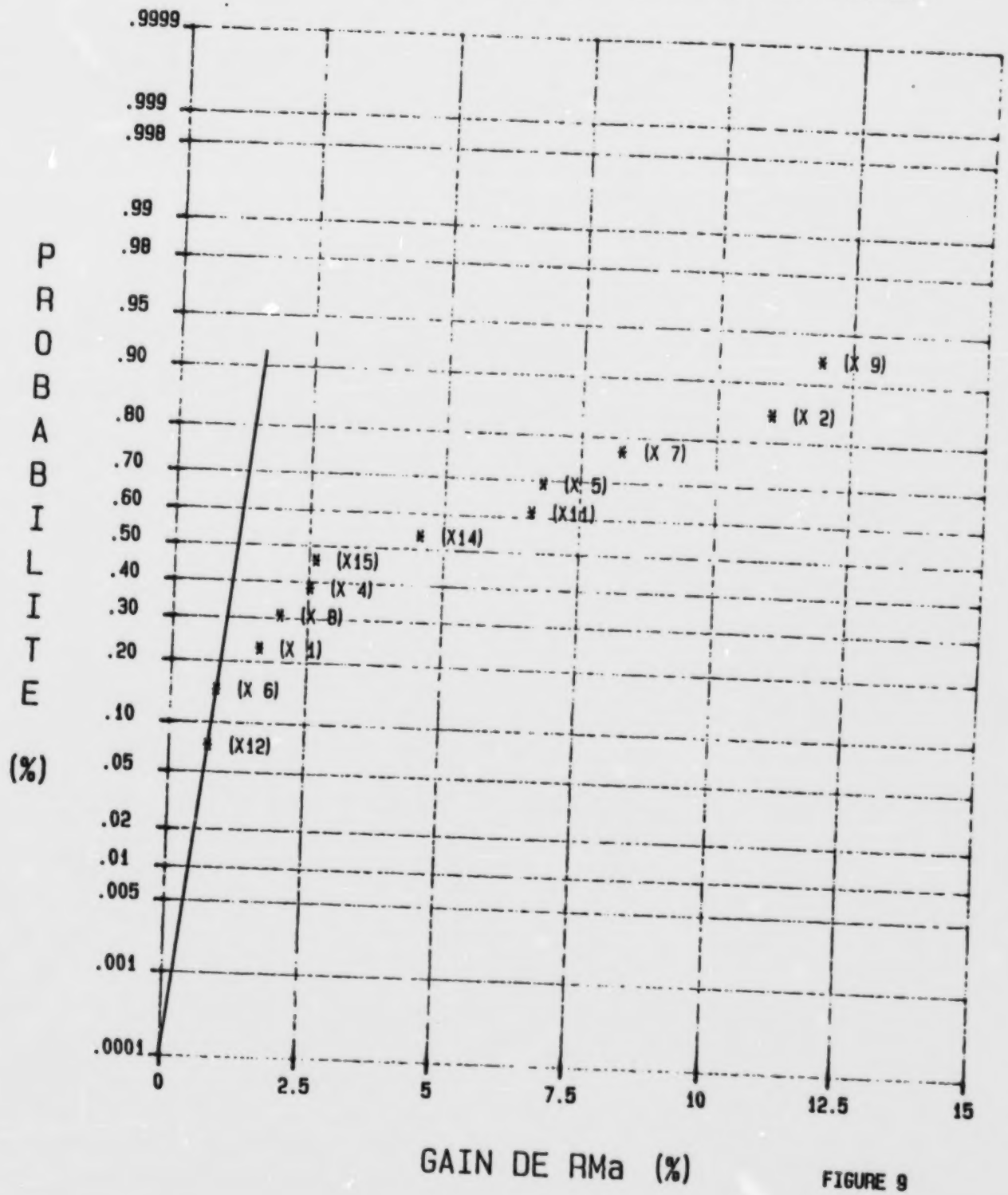


FIGURE 9

ETUDE DU LAITIER DE HAMILTON

PROBABILITE vs GAIN DE RESISTANCE EN FLEXION

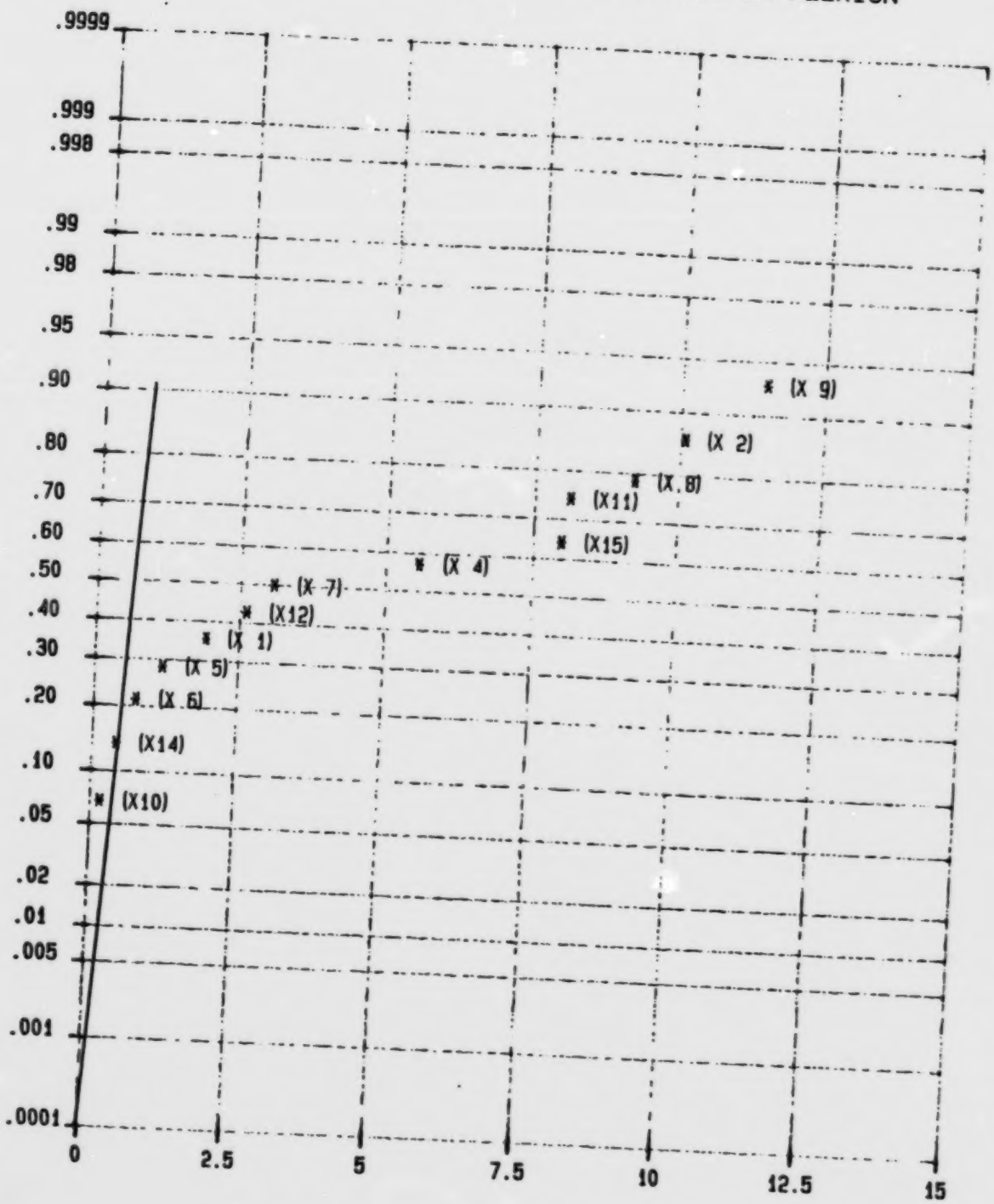


FIGURE 10

RANK	PARAMETER
12	X15 Fibre length
11	X4 Fibre content
10	X8 Silica fume
9	X1 Curing
8	X2 Aggressive water

The insignificant parameters were,

1	X7 Fly ash
2	X14 Binder
3	X6 Fiberization
4	X15 Dispersant

Annex 33 presents the probability contrast sums for the loss in adjusted flexural moduli of rupture caused by each of the exposure modes, including exposure to aggressive waters followed by freeze-thaw exposure. This shows that the parameters that had the greatest influence on loss of strength for the latter exposure mode were, in decreasing order of importance:

RANK	PARAMETER
12	X3 Exposure
11	X14 Binder
10	X5 Fibre length
9	X7 Fly ash

The insignificant parameters were:

1	X9 Pressing
2	X4 Fibre content
3	X12 Air entraining agent
4	X1 Curing

- Flexural testing of products exposed to aggressive waters followed by moisture shock exposure:

  The results are presented in Annex 28. For products exposed to sea water followed by moisture shock exposure the Algoma slag products were 20% stronger than the type 50 cement products. For products exposed to sulfated water followed by moisture shock exposure the Algoma slag products were 40% stronger than the type 50 cement products. If results for sea and sulfated waters are combined, then the Algoma slag products averaged 30% stronger than the type 50 cement products.

  Annex 30 presents the same data together with the data for exposure to

aggressive waters followed by freeze-thaw exposure, and data on freeze-thaw exposure alone. Annex 31, presents the losses in strength due to the various exposures. Annex 32, presents the probability ranks for the contrast sums of the adjusted flexural moduli of rupture after the various exposures. This shows that the most important parameter affecting the resistance to exposure to aggressive waters followed by moisture shock exposure were, in decreasing order of importance:

RANK	PARAMETER
12	X5 Fibre length
11	X4 Fibre content
10	X8 Silica fume
9	X1 Curing

The insignificant parameters were:

1	X12 Air entrainment
2	X6 Fiberization
3	X7 Fly ash
4	X11 Superplasticizer

Annex 33 presents the probability contrast sum rankings for the loss in adjusted flexural moduli of rupture caused by each of the exposure modes, including exposure to aggressive waters followed by moisture shock exposure. This shows that the parameters that had the greatest influence on loss of strength for the latter exposure mode were, in decreasing order of importance:

RANK	PARAMETER
12	X9 Pressing
11	X7 Fly ash
10	X4 Fibre content
9	X13 Exposure
8	X15 Dispersant

The insignificant parameters were:

1	X6 Fiberization
2	X5 Fibre length
3	X12 Air entraining agent
4	X1 Curing

. Flexural testing of products exposed to freezing and thawing alone:

The results are presented in Annex 29. The Algoma slag products averaged 29% stronger than the type 50 cement products.

Annex 30 presents the same data together with the data for the other types of exposure. Annex 31, presents the losses in strength due to the various exposures. The average normalized values for the reduction is adjusted flexural moduli of rupture for each mode of exposure are as follows:

EXPOSURE	AVERAGE % REDUCTION (NORMALIZED)	STANDARD DEVIATION
1. Aggressive waters	25	12
2. Aggressive waters followed by freeze-thaw	30	11
3. Aggressive waters followed by moisture shock	20	13
4. Freezing and thawing	34	4

These results indicate that exposure 4 (freezing and thawing) is the most discriminating (greatest reduction in modulus) and the most precise (lowest standard deviation). Annex 32 presents the probability ranks for the contrast sums of the adjusted flexural moduli of rupture after the various exposures, including exposure to only freezing and thawing, and this shows that the most important parameters affecting the resistance to only freezing and thawing were, in decreasing order of importance:

RANK	PARAMETER
11	X5 Fibre length
10	X4 Fibre content
9	X8 Silica fume
8	X1 Curing
7	X7 Fly ash
6	X9 Pressing

The insignificant parameters were:

1	X11 Superplasticizer
2	X15 Dispersant
3	X12 Air entrainment
4	X6 Fiberization

Annex 33 presents the probability contrast sum rankings for the loss in adjusted flexural moduli of rupture caused by each of the exposure modes, including exposure to only freezing and thawing. This shows that the parameters that had the greatest influence on loss of strength due to only freezing and thawing were, in decreasing order of importance:

RANK	PARAMETER
11	X1 Curing
10	X12 Air entraining agent
9	X9 Pressing
8	X4 Fibre content

The insignificant parameters were:

1	X6 Fiberization
2	X5 Fibre length
3	X14 Binder
4	X15 Dispersant

It is interesting to note that it is frequently the same parameters that have the greatest influence either on the modulus or on the loss in modulus. In the case of the modulus level after exposure the following frequencies of rank were obtained in the order of decreasing importance:

RANK	PARAMETER	FREQUENCY
12 or 11	X5 Fibre length	4
11 or 10	X4 Fibre content	4
10 or 9	X8 Silica fume	4
9 or 8	X1 Curing	4

The insignificant parameters found in the first six ranks were:

PARAMETER	RANK FREQUENCY AT RANK OR LOWER 1	2	3	4	5	6
X7	2	2	3	3	3	3
X6	1	1	3	4	4	4
X11	1	2	2	3	3	3
X14	1	2	2	2	3	3
X12	0	1	2	3	3	4
X15	0	1	1	2	3	4

In the case of the reduction in modulus caused by the exposures the following frequencies of rank were obtained in the order of decreasing importance:

PARAMETER	RANK FREQUENCY AT RANK OR HIGHER 12	11	10	9	8	7
X9 Pressing	2	2	3	3	3	3
X3 Exposure	1	1	1	1	1	1
X1 Curing	1	1	1	1	1	1
X7 Fly ash	0	1	2	3	4	4
X14 Binder	0	1	1	1	1	2
X2 Aggressive water	0	1	1	1	1	1

The insignificant parameters were:

PARAMETER	RANK FREQUENCY AT RANK OR BELOW 1	2	3	4	5	6
X6 Fiberization	2	3	3	3	4	4
X12 Air entraining agent	1	1	3	3	3	3
X5 Fibre length	0	2	2	2	2	2
X1 Curing	0	0	1	3	3	3

Annex 34 and 35 present the comparative qualitiative effects and mass losses of only freeze-thaw exposure for the Algoma and Hamilton studies. It must be kept in mind that the Algoma study consisted of only 100 cylces whereas the Hamilton study consisted of 200 cycles of freeze-thawing. Annex 36 presents the probability rankings of the contrast sums for the changes in mass caused by only the freeze-thaw exposures. This shows that there is no correlation in parametric effects between the Algoma and Hamilton slag products. The data are plotted in Fig. 11 and 12.

A4- August 1987

The statistical analyses of the flexural strength changes caused by various exposure were completed and the following conclusions were drawn:

- Verification of the effect of the cement's origin and the differences in curing: Since the Algoma study was carried out with cement from Ciment St-Laurent cured by immersion, and the Hamilton study had been carried out with Lafarge cement cured in saturated air, it became necessary to ascertain that these differences in cement origin and curing would not significantly affect the comparisons of the results obtained from the two studies. Accordingly, the results were submitted to a Fisher-Snedecor test and the following conclusions were established:

- The origin of the cement did not influence the adjusted flexural moduli of rupture.

ETUDE DU LAITIER D'ALGOMA STEEL

PROBABILITE vs CHANGEMENT DE POIDS (GEL & DEGEL)

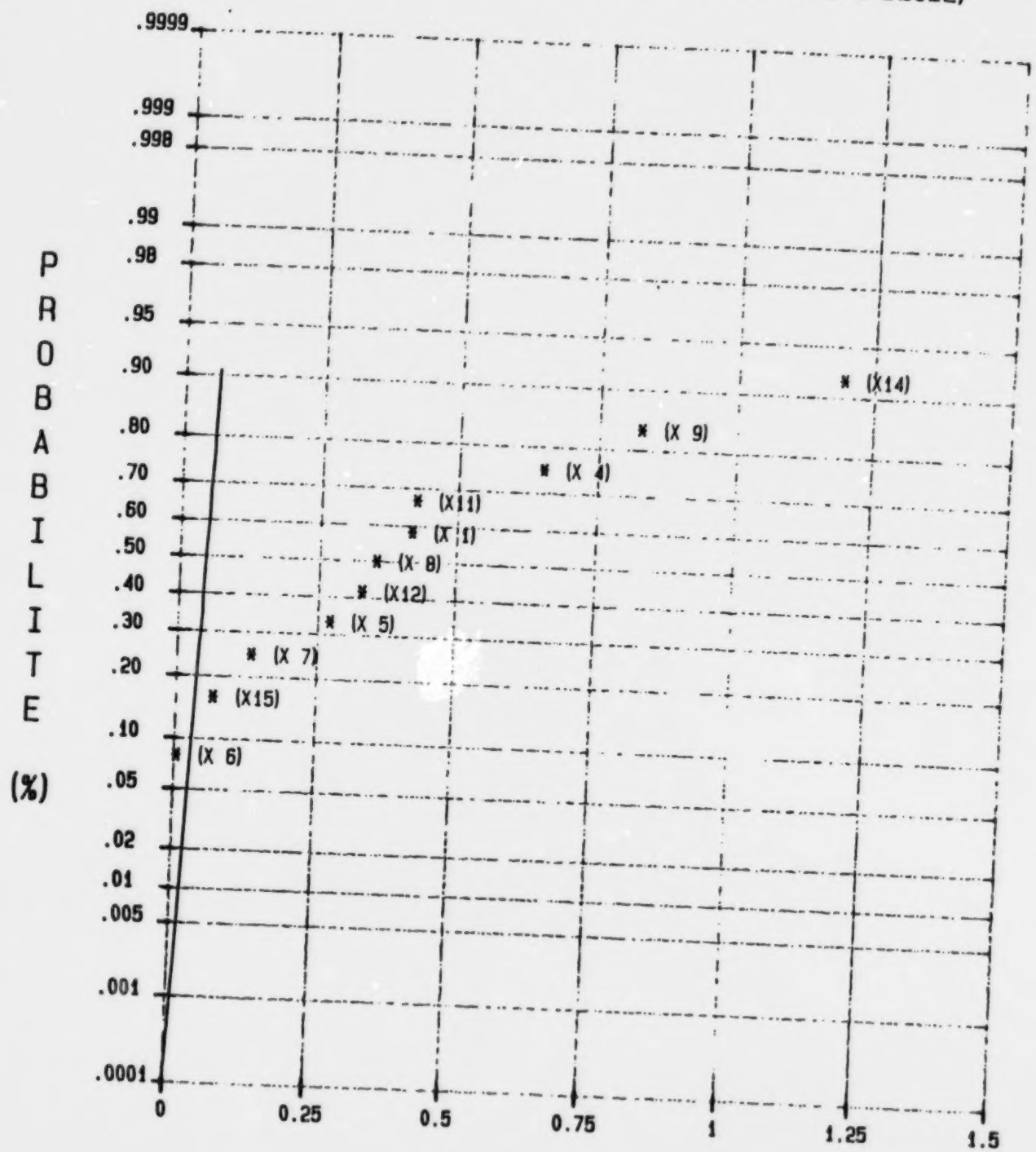


FIGURE 11

ETUDE DU LAITIER DE HAMILTON

PROBABILITE vs CHANGEMENT DE POIDS (GEL & DEGEL)

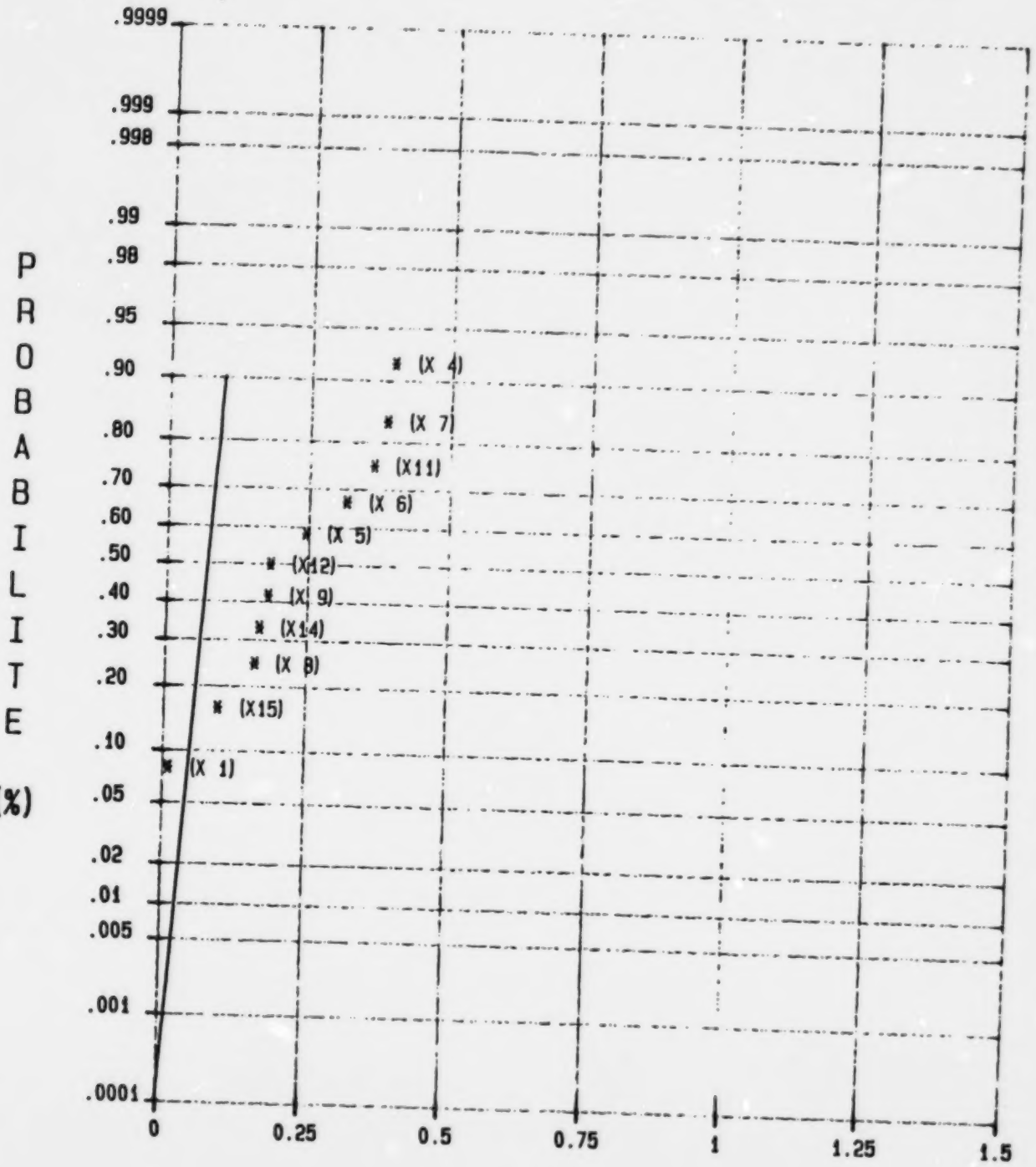


FIGURE 12

- The differences in curing (steam box versus immersion) had a small but significant effect.

- Adjusted flexural moduli of rupture before exposure: the statistical analysis of the data revealed that the adjusted flexural moduli of rupture before exposure for Hamilton and Algoma slag products were not significantly different.

- Adjusted flexural moduli of rupture after exposure:

  It was demonstrated that the losses in modulus caused by the various modes of exposure were influenced by the same parameters for both the Algoma and Hamilton slag products for the following parameters:

  Fibre length,
  Fibre content,
  Superplasticizer.

  The silica fume and curing mode had a major influence on the Algoma slag products only.

- Harkort trials

  The Harkort test were completed on the Algoma slag products and the results are presented in Annex 37 and 38. The Algoma slag products appear generally superior to the type 50 cement products for resistance to Harkort trials.

- Density testing:

  The density before exposure determinations were completed and results are presented in Annex 39 and 42 for both the pressed and unpressed products. This shows that the Algoma slag products average 6.7% less dense than the type 50 cement products while the Hamilton slag products average 6.4% less dense that the type 50 cement products. The Algoma slag products average 2% less dense than the Hamilton slag products.

  The density before exposure data for pressed products only is presented in Annex 40 and 42. This shows that the Algoma slag products averaged 4.1% less dense than the type 50 cement products while the Hamilton slag products averaged 6.0% less dense than the type 50 cement products. The Algoma slag products averaged 0.9% less dense than the Hamilton slag products.

  The density before exposure data for unpressed product only is presented in Annex 41 and 42. This shows that the Algoma slag unpressed products average 10% less dense than the type 50 cement products while the Algoma slag products average 6.9% less dense than type 50 cement products. The Algoma slag products average 5.7% less dense than the Hamilton slag products.

Annex 43 presents the probability contrast sums for the densities of both the pressed and unpressed products prior to exposure for the Algoma and Hamilton studies. This shows that the parameters that had the greatest influence on the density for both studies were, in decreasing order of influence:

RANK	PARAMETER
11	X9 Pressing
10	X5 Fibre length
9	X7 Fly ash
8	X4 Fibre content
7	X14 Binder
6	X8 Silica fume

The insignificant parameters were:

X6 Fiberization
X11 Superplasticizer
X1 Curing mode
X12 Air entraining agent
X15 Dispersant

The densities after exposure to aggressive waters were determined and the results are presented in Annex 42 and 44 for both pressed and unpressed products. The latter shows that the Algoma slag products averaged 5.8% less dense than the type 50 cement products while the Hamilton slag products averaged 6.5% less dense than the type 50 cement products after exposure to the aggressive waters. The Algoma slag products averaged 6.9% less dense than the Hamilton slag products similarly exposed.

The densities after exposure to the aggressive waters for pressed products only is presented in Annex 45. This shows that the Algoma slag products averaged 3.5% less dense than the type 50 cement products after exposure while the Hamilton slag products averaged 6.8% less dense than the type 50 cement products. The Algoma slag products averaged 0.3% more dense than the comparable Hamilton slag products.

The results with unpressed products after exposure are presented in Annex 46. This shows that the Algoma slag products averaged 8.6% less dense while the Hamilton slag products averaged 5.7% less dense than the unpresssed type 50 cement products after exposure to the aggressive waters. The Algoma slag products averaged 6.2% less dense than the comparable unpressed Hamilton slag products after exposure to the aggressive waters.

The densities after exposure to each type of aggressive water (sea and sulfated) for both pressed and unpressed products are presented in Annex 47. This indicates tnat after sea water exposure the Algoma slag products had the same density as the type 50 cement products while the Hamilton slag pro-

ducts averaged 4% less dense than the comparable type 50 cement products. Also the densities of both slag products were equal after sea water exposure. After exposure to sulfated water the Algoma slag products averaged 10.6% less dense than the comparable type 50 cement product while the Hamilton slag products averaged 17% less dense than the comparable type 50 cement products. Also the Algoma slag products averaged 5.1% denser than the Hamilton slag products after exposure to sulfated water.

Annex 48 presents the probability contrast sums for density after exposure to the aggressive waters. This reveals that the parameters that have the greatest influence upon the densities after exposure to the aggressive waters are the following in decreasing order of importance:

X9	Pressing
X5	Fibre length
X7	Fly ash
X4	Fibre content

The above parameters are the same ones that most influence the density before exposure to aggressive waters.

Annex 49, presents the increases in density caused by exposure to the aggressive waters. No correlation can be observed between the parameters that most influence each study (Algoma and Hamilton).

. Porosity testing:

The porosity was determined on all the products before exposure to aggressive waters and the results are presented in Annex 50. The Algoma slag products prior to exposure are seen to average 16.9% more porous than the type 50 cement products while the Hamilton slag products average 19.5% more porous than the type 50 cement products. The Algoma slag products prior to exposure average 66.4% more porous than the Hamilton slag products and this is a major difference. On that basis, the Hamilton slag products would be expected to have a much better durability but this has not been observed from comparisons of flexural strength and density between the two slag products after various exposure modes.

Annex 51 presents the porosity data for the pressed products only. The porosities are shown to average 42% higher for Algoma slag products prior to exposure than type 50 cement products while the Hamilton slag products average 20% higher than type 50 cement products. The porosities for both slag products were equal and averaged 19.3% higher than the type 50 cement products.

Annex 52 presents the porosity data for the unpressed products only. The porosities are shown to average 17% higher for unpressed Algoma slag products prior to exposure than type 50 cement products while the Hamilton slag products average 11% higher porosities than type 50 cement products. The Algoma slag product averaged 22% higher porosities than the compara-

ble Hamilton slag unpressed products prior to exposure.

Annex 63 presents the probability ranks for the contrast sums of the porosity before exposure to the aggressive waters. This shows that the most significant parameters affecting porosity are, in decreasing order of importance:

RANK	PARAMETER
11	X9 Pressing
10	X5 Fibre length
9	X7 Fly ash
8	X4 Fibre content

The insignificant parameters appear to be:

X6 Fiberization
X12 Air entraining agent
X11 Superplasticizer
X15 Dispersant

The porosities of all products before and after exposure to aggressive waters are presented in Annex 53. Annex 54 presents the porosity data for products after exposure to the aggressive waters. This shows that the Algoma slag products after exposure to the aggressive products averaged 30% higher porosity than the comparable type 50 cement products while the Hamilton slag products averaged 11% higher porosity than the type 50 cement products. The Algoma slag products are shown to have 47% higher porosity than the Hamilton slag products after exposure to the aggressive waters.

Annex 55 presents the porosity data for only the pressed products after exposure to the aggressive waters. This shows that the Algoma slag products averaged 123% higher porosity than the comparable type 50 cement products while the Hamilton slag products averaged 144% higher porosity than the type 50 cement products. The Algoma slag products are shown to have 13% lower porosity than the pressed Hamilton slag products after exposure to the aggressive waters.

Annex 56 presents the porosity data for only the unpressed products after exposure to the aggressive waters. This shows that the Algoma slag products averaged 29% higher porosity than the comparable type 50 cement products while the Hamilton slag products averaged 12% higher porosity than the comparable type 50 cement products. The unpressed Algoma slag products are shown to have 25% higher porosity than the Hamilton slag products after exposure to the aggressive waters.

Annex 57 presents the porosity data for only the products exposed to sea water. This shows that the Algoma slag products averaged 6% lower porosity than the comparable type 50 cement products while the Hamilton slag products averaged 17% more porous than the type 50 cement products exposed to sea water. The Algoma slag products averaged 12% less porous

than the Hamilton slag products after exposure to the sea water.

Annex 58 presented the porosity data for only those products exposed to sulfated water. This shows that the Algoma slag products averaged 43% higher in porosity than the comparable type 50 cement products while the Hamilton slag products averaged 58% higher in porosity than the type 50 cement products exposed to sulfated water. The Algoma slag products are shown to average 6.6% higher in porosity than the Hamilton slag products after exposure to the sulfated water.

Annex 59, presents the probability rankings of the contrast sums for porosity after exposure to aggressive waters. This shows that the most significant parameters affecting porosity are, in decreasing order of importance:

RANK	PARAMETER
13 or 12	X9 Pressing
12 or 11	X5 Fibre length
11 or 10	X7 Fly ash
10 or 9	X4 Fibre content

The insignificant parameters are:

X6 Fiberization
X12 Air entraining agent
X1 Curing
X8 Silica fume
X11 Superplasticizer

It is worthy of note that most of the above parameters had the same influence on the porosity before exposure to aggressive waters.

Annex 60 presents the probability ranks for increases in porosity caused by exposure to aggressive waters. There appears to be no correlation between the parameters that most influenced the Algoma study and those parameter that most influenced the Hamilton Study.

Annex 61 presents the increases in porosity caused by exposure to the aggressive waters for all the products. This shows that the absolute increase in porosity as well as the percentage increase was slightly greater for the Algoma Study than for the Hamilton Study.

Annex 62 presents the decreases in porosity caused by exposure to the aggressive waters for only the slag products. This shows that both slag products underwent decreases in porosity of 34% caused by exposure to the aggressive waters. The absolute decrease in porosity of the Algoma slag products was 24% less than that of the Hamilton slag products.

Annex 64 presents the probability ranks for the contrast sums for porosity changes caused by exposure to the aggressive waters. This indicates that the parameters that had the greatest influence on the porosities after exposure to aggressive waters were, in decreasing order of importance:

RANK	PARAMETER
13 or 11	X5 Fibre length
12	X9 Pressing
11 or 9	X2 Aggressive water

The insignificant parameters were:

X12 Air entraining agent
X15 Dispersant
X6 Fiberization
X11 Superplasticizer

(B) SUMMARY OF WORK PLANNED FOR SEPTEMBER 1987

Writing the final report.

(C) STATEMENT AS TO WHETHER THE WORK IS PROCEEDING ACCORDING TO PLAN

The work is proceeding according to plan except for a six month delay and a substantial over expenditure.

(D) IDENTIFICATION OF POTENTIAL PROBLEM AREAS WHICH MAY AFFECT THE PROGRESS OFF THE WORK AND THE PROPOSED SOLUTIONS TO THOSE PROBLEMS.

One potential problem area is a depleted budget. The proposed solution is to assign the remainder of the work to personnel not otherwise engaged.

(E) SUFFICIENT SKETCHES, DIAGRAMS, PHOTOGRAPHS AND DISCUSSION OF PROGRESS AND PROBLEMS TO ALLOW THE SCIENTIFIC AUTHORITY AND THE SCIENCE CONTRACTING OFFICER TO EVALUATE THE PROGRESS OF THE WORK.

Refer to Fig. 3,4,7,8,9,10, 11 and 12.
Refer also to Annex 1 to 64.

(F) CONTRACT PLAN

Actual and forecast expenditures at the end of May, June, July and August 1987 are presented in Appendix A. Expenditures charged to date (end of August 1987) against this project budget are $8230.59 versus the foreseen expenditures of $8230.59.

CONCLUSIONS

The work contracted for has been done despite the budget shortfall.

Progress of the work against our contract plan is attached as Appendix B.

Technical conclusions are presented in Appendix C.

MC/pg

Annex 1

FLEXURAL MODULUS OF RUPTURE PRIOR TO EXPOSURE

for shorter fibres with a low degree of fiberization

FIBRE LENGTH	LOW (7D700)							
FIBRE CONTENT	HIGH (20%)							
FIBERIZATION	LOW (56 DM^2/g)							
	type 50 cement				slag			
Fly ash	yes	no			no	yes		
Silica fume	yes	no			yes	no		
Air entrainment	no	yes			no	yes		
Superplasticizer	yes	yes			no	no		
Dispersant	no	yes			yes	no		
Compression	yes	yes			no	no		
Slag study	Algoma		Hamilton		Algoma		Hamilton	
Code	502.2.2	502.2	512.2.2	512.2	508.2.2	508.2	514.2.2	514.2
Curing:								
Saturated air	yes	yes	--	--	yes	yes	--	--
Immersed	--	--	yes	--	--	--	--	--
Steam box	--	--	--	yes	--	--	yes	yes
Flexural modulus of rupture, MPa	37.7	35.8	35.2	31.3	43.1	42.2	35.6	34.2
Difference: (Algoma-Hamilton)x 100 /(Hamilton), %	+5.3		+12.5		+2.1		+4.1	

Annex 2

FLEXURAL MODULUS OF RUPTURE PRIOR TO EXPOSURE

for shorter fibres with a high degree of fiberization

FIBRE LENGTH	LOW (7D700)							
FIBRE CONTENT	HIGH (20%)							
FIBERIZATION	LOW (56 DM^2/g)							
	type 50 cement				slag			
Fly ash	yes	no			no	yes		
Silica fume	yes	no			yes	no		
Air entrainment	yes	no			yes	no		
Superplasticizer	yes	yes			no	no		
Dispersant	yes	nos			no	yes		
Compression	no	no			yes	yes		
Slag study	Algoma	Hamilton	Algoma	Hamilton	Algoma	Hamilton	Algoma	Hamilton
Code	605.2.2	605.2	615.2.2	615.2	603.2.2	603.2	619.2.2	619.2
Curing:								
Saturated air	yes	yes	--	--	yes	yes	--	--
Immersed	--	--	yes	--	--	--	yes	--
Steam box	--	--	--	yes	--	--	yes	yes
Flexural modulus of rupture, MPa								
	31.1	37.3	32.7	27.5	26.5	29.6	27.4	26.3
Difference: (Algoma-Hamilton) x 100/ (Hamilton), %								
	-16.6		-18.9		-10.5		+4.2	

Annex 3

FLEXURAL MODULUS OF RUPTURE PRIOR TO EXPOSURE

for longer fibres with a low degree of fiberization

FIBRE LENGTH	HIGH(4T500)							
FIBRE CONTENT	LOW (20%)							
FIBERIZATION	LOW (53 DM^2/g)							
	type 50 cement				slag			
Fly ash	yes	no			no		yes	
Silica fume	no	yes			no		yes	
Air entrainment	yes	no			yes		no	
Superplasticizer	no	no			yes		yes	
Dispersant	no	yes			yes		no	
Compression	yes	yes			no		no	
Slag study	Algoma	Hamilton	Algoma	Hamilton	Algoma	Hamilton	Algoma	Hamilton
Code	707.2.2	707.2	713.2.2	713.2	701.2.2	701.2	711.2.2	711.2
Curing:								
Saturated air	yes	yes	--	--	yes	yes	--	--
Immersed	--	--	yes	--	--	--	yes	--
Steam box	--	--	--	yes	--	--	--	yes
Flexural modulus of rupture, MPa								
	34.5	37.2	59.8	54.6	44.4	51.7	54.6	60.7
Difference: (Algoma-Hamilton)x100/Hamilton),%								
	-7.3		+9.5		-14.1		-10.0	

Annex 4

FLEXURAL MODULUS OF RUPTURE PRIOR TO EXPOSURE

for shorter fibres with a low degree of fiberization

FIBRE LENGTH	HIGH (4T500)							
FIBRE CONTENT	HIGH (20%)							
FIBERIZATION	LOW (56 DM^2/g)							
	type 50 cement				slag			
Fly ash	yes	no			no	yes		
Silica fume	no	yes			no	yes		
Air entrainment	no	yes			no	yes		
Superplasticizer	no	no			yes	yes		
Dispersant	yes	no			no	yes		
Compression	no	no			yes	yes		
Slag study	Algoma	Hamilton	Algoma	Hamilton	Algoma	Hamilton	Algoma	Hamilton
Code	804.2.2	804.2	810.2.2	810.2	806.2.2	806.2	816.2.2	816.2
Curing:								
Saturated air	yes	yes	--	--	yes	yes	--	--
Immersed	--	--	yes	--	--	--	yes	--
Steam box	--	--	--	yes	--	--	--	yes
Flexural modulus of rupture, MPa								
	56.5	54.6	73.4	62.7	50.2	56.6	58.4	68.8
Difference: (Algoma-Hamilton) x 100/(Hamilton), %								
	+3.5		+17.1		-11.3		-15.1	

ANNEX 5

TABLEAU 1
COMPARAISON DE LA RESISTANCE EN FLEXTION
AVANT LE TRAITEMENT DANS LES EAUX AGRESSIVES
SERIE: 2.2 ETUDE DU LAITIER D'ALGOMA STEEL
2. ETUDE DU LAITIER DE HAMILTON

GRADE DE FIBRE			7D700							
NIVEAU D'ESSAIS	LONGEUR		BAS							
	OUVERTURE		BAS(56dm2/g)							
	CONCENTRATION		HAUT(20%)							
TYPE DE CIMENT			50				LAITIER			
CODE			502		512		508		514	
SERIE			2.2	2	2.2	2	2.2	2	2.2	2
ADDITIFS:										
CENDRE VOLANTE			OUI		NON		NON		OUI	
FUMEE DE SILICE			OUI		NON		OUI		NON	
ADJUVANTS:										
ENTRAINEUR D'AIR			NON		OUI		NON		OUI	
SUPERPLASTIFIANT			OUI		OUI		NON		NON	
DISPERSANT			NON		OUI		OUI		NON	
COMPRESSION			OUI		OUI		NON		NON	
MURISSEMENT										
CHAMBRE HUMIDE			OUI	OUI	NON	NON	OUI	OUI	NON	NON
IMMERSION DANS L'EAU			NON	NON	OUI	NON	NON	NON	OUI	NON
BOITE A VAPEUR			NON	NON	NON	OUI	NON	NON	NON	OUI
RESISTANCE EN FLEXION D=1,6, MPa SATURE, SENS DE MARCHE			37.7	35.8	35.2	31.3	43.1	42.2	35.6	34.2
DIFFERENCE (%) (2.2)-(2) / (2) x 100			+5.3		+12.5		+2.1		+4.1	

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ANNEX 6

TABLEAU 2
COMPARAISON DE LA RESISTANCE EN FLEXTION
AVANT LE TRAITEMENT DANS LES EAUX AGRESSIVES
SERIE: 2.2 ETUDE DU LAITIER D'ALGOMA STEEL
2. ETUDE DU LAITIER DE HAMILTON

GRADE DE FIBRE		7D700							
NIVEAU D'ESSAIS	LONGEUR	BAS							
	OUVERTURE	HAUT (117dm2/g)							
	CONCENTRATION:	BAS (10%)							
TYPE DE CIMENT		50				LAITIER			
CODE		605		615		603		619	
SERIE		2.2	2	2.2	2	2.2	2	2.2	2
ADDITIFS:									
CENDRE VOLANTE		OUI		NON		NON		OUI	
FUMEE DE SILICE		OUI		NON		OUI		NON	
ADJUVANTS:									
ENTRAINEUR D'AIR		OUI		NON		OUI		NON	
SUPERPLASTIFIANT		OUI		OUI		NON		NON	
DISPERSANT		OUI		NON		NON		OUI	
COMPRESSION		NON		NON		OUI		OUI	
MURISSEMENT									
CHAMBRE HUMIDE		OUI	OUI	NON	NON	OUI	OUI	NON	NON
IMMERSION DANS L'EAU		NON	NON	OUI	NON	NON	NON	OUI	NON
BOITE A VAPEUR		NON	NON	NON	OUI	NON	NON	NON	OUI
RESISTANCE EN FLEXION D=1,6, MPa SATURE, SENS DE MARCHE		31.1	37.3	32.7	27.5	26.5	29.6	27.4	26.3
DIFFERENCE (%) (2.2)-(2) / (2) x 100		-16.6		+18.9		-10.5		+4.2	

ANNEX . 7

TABLEAU 3
COMPARAISON DE LA RESISTANCE EN FLEXTION
AVANT LE TRAITEMENT DANS LES EAUX AGRESSIVES
SERIE: 2.2 ETUDE DU LAITIER D'ALGOMA STEEL
2. ETUDE DU LAITIER DE HAMILTON

GRADE DE FIBRE		4T500							
NIVEAU D'ESSAIS	LONGEUR OUVERTURE	HAUT							
	CONCENTRATION	BAS (53 dm2/g)							
		BAS (10%)							
TYPE DE CIMENT		50				LAITIER			
CODE		707		713		701		711	
SERIE		2.2	2	2.2	2	2.2	2	2.2	2
ADDITIFS:									
CENDRE VOLANTE		OUI		NON		NON		OUI	
FUMEE DE SILICE		NON		OUI		NON		OUI	
ADJUVANTS:									
ENTRAINEUR D'AIR		OUI		NON		OUI		NON	
SUPERPLASTIFIANT		NON		NON		OUI		OUI	
DISPERSANT		NON		OUI		OUI		NON	
COMPRESSION		OUI		OUI		NON		NON	
MURISSEMENT									
CHAMBRE HUMIDE		OUI	OUI	NON	NON	OUI	OUI	NON	NON
IMMERSION DANS L'EAU		NON	NON	OUI	NON	NON	NON	OUI	NON
BOITE A VAPEUR		NON	NON	NON	OUI	NON	NON	NON	OUI
RESISTANCE EN FLEXION D=1,6, MPa SATURE, SENS DE MARCHE		34.5	37.2	59.8	54.6	44.4	51.7	54.6	60.7
DIFFERENCE (%) (2.2)-(2) / (2) x 100		-7.3		+9.5		-14.1		-10.0	

ANNEX 8

TABLEAU 4
COMPARAISON DE LA RESISTANCE EN FLEXTION
AVANT LE TRAITEMENT DANS LES EAUX AGRESSIVES
SERIE: 2.2 ETUDE DU LAITIER D'ALGOMA STEEL
2. ETUDE DU LAITIER DE HAMILTON

GRADE DE FIBRE		4T500							
NIVEAU D'ESSAIS	LONGEUR	HAUT							
	OUVERTURE	HAUT (110 dm2/g)							
	CONCENTRATION	HAUT (20 %)							
TYPE DE CIMENT		50				LAITIER			
CODE		804		810		806		816	
SERIE		2.2	2	2.2	2	2.2	2	2.2	2
ADDITIFS:									
CENDRE VOLANTE		OUI		NON		NON		OUI	
FUMEE DE SILICE		NON		OUI		NON		OUI	
ADJUVANTS:									
ENTRAINEUR D'AIR		NON		OUI		NON		OUI	
SUPERPLASTIFIANT		NON		NON		OUI		OUI	
DISPERSANT		OUI		NON		NON		OUI	
COMPRESSION		NON		NON		OUI		OUI	
MURISSEMENT									
CHAMBRE HUMIDE		OUI	OUI	NON	NON	OUI	OUI	NON	NON
IMMERSION DANS L'EAU		NON	NON	OUI	NON	NON	NON	OUI	NON
BOITE A VAPEUR		NON	NON	NON	OUI	NON	NON	NON	OUI
RESISTANCE EN FLEXION C=1,6, MPa SATURE, SENS DE MARCHE		56.5	54.6	73.4	62.7	50.2	56.6	58.4	68.8
DIFFERENCE (%) $\frac{(2.2)-(2)}{(2)} \times 100$		+3.5		+17.1		-11.3		-15.1	

ANNEX 9

RESISTANCE TO AGGRESSIVE WATERS: COMPARISON OF ALGOMA SLAG AGAINST TYPE 50 CEMENT PRODUCTS.

Trial No.	Sample code		Resistance to aggressive waters	
	Type 50 cement	Algoma slag	Sea Water	Sulfated Water
1	502		good	----
2		508	----	good
3	512		slight spalling	----
4		514	----	good
5		603	good	----
6	605		----	good
7		609	good	----
8	615		----	good
9		701	slight spalling	----
10	707		----	good
11		711	good	----
12	713		----	slight spalling
13	804		slight spalling	----
14		806	----	good
15	810		slight spalling	----
16		816	----	good

ANNEX 10

RESISTANCE TO COMBINE EXPOSURE TO AGGRESSIVE WATERS AND TO FREEZING AND THAWING.

Trial NO.	Sample code		Resistance to combined exposure to aggressive waters and freezing and thawing	
	Type 50 cement	Algoma slag	Sea Water	Sulfated Water
1	502		slight spalling	----
2		508	----	good
3	512		----	good
4		514	good	----
5		603	----	good
6	605		slight spalling	----
7		609	good	----
8	615		----	good
9		701	slight spalling	----
10	707		----	good
11		711	----	good
12	713		slight spalling	----
13	804		----	slight spalling
14		806	slight spalling	----
15	810		moderate spalling	----
16		816	----	good

ANNEX 11

RESISTANCE TO COMBINED EXPOSURE TO AGGRESSIVE WATERS FOLLOWED BY MOISTURE SHOCKS: COMPARISON OF ALGOMA SLAG PRODUCTS AGAINST TYPE 50 CEMENT PRODUCTS

Trial NO.	Sample code		Resistance to combined exposure to aggressive waters and moisture shocks	
	Type 50 cement	Algoma slag	Sea water	Sulfated water
1	502		----	good
2		508	----	incipient delamination
3	512		slight spalling	----
4		514	good	----
5		603	good	----
6	605		slight spalling	----
7		609	----	incipient delamination
8	615		----	slight spalling
9		701	----	moderate spalling
10	707		----	good
11		711	good	----
12	713		slight spalling	----
13	804		moderate spalling	----
14		806	incipient delamination	----
15	810		----	delaminated
16		816	----	incipient delamination

ANNEX 12

Tableau 1- Comparaison des états des plaques après exposition:
- aux eaux agressives,
- aux eaux agressives + gel & dégel
- aux eaux agressives + choc hydrique -étude du laitier d'Algoma Steel

NO. ESSAI	CODE DES PLAQUES		EAUX AGRESSIVES		EAUX AGRESSIVES + GEL & DEGEL		EAUX AGRESSIVES + CHOC HYDRIQUE	
	CIMENT T-50	LAITIER	EM -	ES +	EM -	ES +	EM -	ES +
1	502		B		EL			B
2		508		B		B		SD
3	512		EL			B	EL	
4		514		B	B		B	
5		603	B			B	B	
6	605			B	EL		EL	
7		609	B		B			SD
8	615			B		B		EL
9		701	EL		EM			EM
10	707			B		B		B
11		711	B			B	B	
12	713			EL	EL		EL	
13	804		EL			EL	EM	
14		806		B	EL		SD	
15	810		EL		EM			D
16		816		B		B		SD

LEGENDES:
- B: bon
- EL: Ecaillage léger
- EM: Ecaillage moyen
- SD: Signe de délamination
- D: Délaminé

ANNEX 13

EXPOSURE TO FREEZING AND THAWING ONLY: 100 CYCLES FOR ALGOMA SLAG PRODUCTS VERSUS 74 CYCLES FOR TYPE 50 CEMENT PRODUCTS.

Trial No.	Sample Code		Resistance to freezing and thawing	
	Type 50 cement	Algoma SLag	after 74 cycles	after 100 cycles
1	502		good	----
2		508	----	good
3	512		spalled	----
4		514	----	good
5		603	----	good
6	605		good	----
7		609	----	good
8	615		spalled	----
9		701	----	spalled
10	707		good	----
11		711	----	spalled
12	713		good	----
13	804		spalled	----
14		806	----	good
15	810		spalled	----
16		816	----	good

ANNEX 14

HARKORT TRIALS

Temperature	Type 50 cement products	Algoma slag cement products
100°C	No apparent deterioration	No apparent deterioration
120°C	No apparent deterioration	No apparent deterioration
140°C	No apparent deterioration	No apparent deterioration
160°C	Light yellowing	Light yellowing
180°C	Light yellowing	Light yellowing
200°C	Specimens containing fly ash turned dark gray *Fibres appeared at the surface of samples coded 701 and 711	Specimens containing fly ash turned dark gray *Fibres appeared at the surface of samples coded 713, 804 & 810
210°C	Darker yellowing	Darker yellowing
220°C	Darker yellowing	Darker yellowing
230°C	Darker yellowing	Darker yellowing
240°C	Samples coded 804 show signs of spalling	Darker yellowing
250°C	Still darker yellowing	Still darker yellowing
260°C	*Slight spalling for samples coded 713, 804 and 810	*Slight spalling for samples coded 701
270°C	No change	No change
280°C	Fibres appeared at the surface of samples coded 512, 615 and 707 Incipient spalling for samples coded 605 Actually spalled 707, 804 and 810	Fibres appeared at the surface of samples coded 508, 514, 603 and 816 Incipient spalling for samples coded 701 and 711 None actually spalled

* Note that all samples with these codes contained longer fibre 4T500

ANNEX 15

Tableau 2- Comparaison des résultats des essais Harkort des études du laitier d'Algoma Steel et du laitier de Hamilton.

TEMPERATURE °C	ETUDE DU LAITIER D'ALGOMA STEEL	ETUDE DU LAITIER DE HAMILTON
100	pas de changement de l'état des plaques	pas de changement de l'état des plaques
120	-id-	-id-
140	-id-	-id-
160	plaques de couleur claire jaunissement légèrement.	plaques de couleur claire jaunissement légèrement-Arrêt de l'expérience.
180	-id-	
200	Dégradation de couleur gris foncé des plaques réalisées avec la cendre volante Apparition de fibres sur la surface des plaques: 701, 711,713 804, 810	
210	Couleur jaune devient plus foncée	
220	Pas de changement	
230	-id-	
240	Plaques 804 ont des signes d'écaillage	
250	Couleur jaune devient plus foncée	
260	Ecaillées légèrement: 701,713,804,810	
270	Pas de changement	
280	Bonnes plaques: 502, 609, 806 Apparition de fibres sur la surface: 508, 512, 514, 603, 615, 707, 816 Signe d'écaillage: 605,701,711 Ecaillées: 717, 804, 810	

ANNEX 16

FLEXURAL MODULI OF RUPTURE ADJUSTED TO A DENSITY OF 1.6 g/cm³ FOR TYPE 50 CEMENT AND SLAG PRODUCTS CURED IN MOIST AIR.

Trial No.	Sample code	Adjusted flexural moduli of rupture, MPa					
		Algoma study types of binder			Hamilton study types of binder		
		Type 50 cement	Algoma slag	Combined	Type 50 cement	Hamilton slag	Combined
1	502	37.7	----		35.8	----	
2	508	----	43.1		----	42.2	
5	603	----	26.5		----	29.6	
6	605	31.1	----		----	----	
9	701	----	44.4		----	51.7	
10	707	34.5	----		37.2	----	
13	804	56.5	----		54.6	----	
14	806	----	50.2		----	56.6	
average		40	41	40.5	41	45	43
standard deviation		11	10	10	8.9	12	10

ANNEX 17

FLEXURAL MODULI OF RUPTURE ADJUSTED TO A DENSITY OF 1.6 g/cm^3 FOR TYPE 50 CEMENT AND SLAG PRODUCTS WHEN CURED BY IMMERSION FOR ALGOMA SLAG PRODUCTS, AND IN A STEAM BOX FOR HAMILTON SLAG PRODUCTS.

		Adjusted flexural moduli of rupture, MPa					
Trial	Sample	Algoma study curing by immersion			Hamilton study cured in a steam box		
No.	code	Type 50 cement	Algoma slag	Combined	Type 50 cement	Hamilton slag	Combined
3	512	35.2	----		31.3	----	
4	514	----	35.6		----	34.2	
7	609	----	27.4		----	26.3	
8	615	32.7	----		27.5	----	
11	711	----	54.6		----	60.7	
12	713	59.8	----		54.6	----	
15	810	73.4	----		62.7	----	
16	816	----	58.4		----	68.8	
average		50	44	47	44	48	46
standard deviation		20	15	17	17	20	18

ANNEX 18

TABLEAU 9: ETUDE DU LAITIER D'ALGOMA STEEL ET DU LAITIER DE HAMILTON.

COMPARAISON DE LA RESISTANCE EN FLEXION AJUSTEE (D=1.6) AVANT EXPOSITION AUX EAUX AGRESSIVES.

- ECHANTILLONS: SATURES, SENS DE MARCHE.

MRa, MPA

ETUDE		LAITIER D'ALGOMA STEEL			LAITIER DE HAMILTON		
ESSAI No	CODE	TYPE DE CIMENT 50	LAITIER	LAITIER & 50	50	LAITIER	LAITIER & 50
		MPa	MPa	MPa	MPa	MPa	MPa
1	502*	37.7		37.7	35.8		35.8
2	508*		43.1	43.1		42.2	42.2
3	512	35.2		35.2	31.3		31.3
4	514		35.6	35.6		34.2	34.2
5	603*		26.5	26.5		29.6	29.6
6	605*	31.1		31.1	37.3		37.3
7	609		27.4	27.4		26.3	26.3
8	615	32.7		32.7	27.5		27.5
9	701*		44.4	44.4		51.7	51.7
10	707*	34.5		34.5	37.2		37.2
11	711		54.6	54.6		60.7	60.7
12	713	59.8		59.8	54.6		54.6
13	804*	56.5		56.5	54.6		54.6
14	806*		50.2	50.2		56.6	56.6
15	810	73.4		73.4	62.7		62.7
16	816		58.4	58.4		68.8	68.8
MOYENNE		45.1	42.5	33.7	42.6	46.3	33.0
DEVIATION STANDARD		15,9	11.9	5.5	12.8	15.5	5.4

REMARQUE: * PLAQUE MURIE DANS LA CHAMBRE HUMIDE.

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ANNEX 19

RANKING OF PROBABILITY CONTRAST SUMS FOR THE ADJUSTED FLEXURAL MODULI OF RUPTURE BEFORE EXPOSURE FOR ALGOMA AND HAMILTON SLAG PRODUCTS

Parameter		PROBABILITY CONTRAST SUMS				Absolute difference in rank
		ALGOMA SLAG PRODUCTS		HAMILTON SLAG PRODUCTS		
No.	Description	MPa	Rank	MPa	Rank	
X1	Curing	6.6	7	2.6	8	1
X4	Fibre content	0.2	1	2.1	6	5
X5	Fibre length	20.1	11	22.8	11	0
X6	Fiberization	1.4	2	2.0	5	3
X7	Fly ash	8.4	9	4.6	9	0
X8	Silica fume	1.6	3	0.7	2	1
X9	Pressing	9.9	10	8.3	10	0
X11	Superplasticizer	6.3	6	0.9	3	3
X12	Air entrainment	2.9	4	0.7	1	3
X14	Binder	8.0	8	1.6	4	4
X15	Dispersant	4.1	5	2.5	7	2
	average					2

ANNEX 20

TABLEAU: 10: ETUDE DU LAITIER D'ALGOMA STEEL ET DU LAITIER DE HAMILTON.

RANG DE PROBABILITE DES SOMMES DE CONTRASTE DE LA RESISTANCE EN FLEXION AJUSTEE A (D=1.6),AVANT EXPOSITION AUX EAUX AGRESSIVES.

ECHANTILLONS: SATURES, SENS DE MARCHE.

RANG No	PROBABILITE	ETUDE DU LAITIER D'ALGOMA STEEL	ETUDE DU LAITIER DE HAMILTON
	1/11+1=	MPa	MPa
1	0.083	(-) 0.212(X 4)	(-) 0.688(X12)
2	0.167	1.412(X 6)	(-) 0.713(X 8)
3	0.250	(-) 1.587(X 8)	(-) 0.938(X11)
4	0.333	(-) 2.862(X12)	(-) 1.637(X14)
5	0.417	(-) 4.050(X15)	1.962(X 6)
6	0.500	(-) 6.275(X11)	(-) 2.088(X 4)
7	0.583	6.638(X 1)	(-) 2.462(X15)
8	0.667	(-) 7.975(X14)	2.638(X 1)
9	0.750	(-) 8.400(X 7)	(-) 4.637(X 7)
10	0.833	(-) 9.925(X 9)	(-) 8.313(X 9)
11	0.9171	20.313(X 5)	22.838(X 5)

ANNEX 21

FLEXURAL MODULI OF RUPTURE ADJUSTED TO A CONSTANT DENSITY OF 1.6g/cm³ AFTER EXPOSURE TO CORROSIVE WATERS FOR TYPE 50 CEMENT AND SLAG PRODUCTS WHEN CURED IN SATURATED AIR.

		Adjusted flexural moduli of rupture, MPa					
Trial	Sample	Algoma study			Hamilton study		
No.	code	Type 50 cement	Algoma slag	Combined	Type 50 cement	Hamilton slag	Combined
1	502	35.1	----		33.9	----	
2	508	----	31.9		----	40.9	
5	603	----	23.7		----	24.0	
6	605	27.1	----		34.2	----	
9	701	----	38.6		----	45.7	
10	707	36.0	----		38.3	----	
13	804	47.5	----		52.7	----	
14	806	----	52.0		----	61.4	
average		36	37	36	40	43	41
standard deviation		8	12	10	9	15	12

ANNEX 22

FLEXURAL MODULI OF RUPTURE ADJUSTED TO A CONSTANT DENSITY OF 1.6 g/cm³ AFTER EXPOSURE TO CORROSIVE WATERS FOR TYPE 50 CEMENT AND SLAG PRODUCTS WHEN CURED BY IMMERSION FOR THE ALGOMA STUDY AND IN A STEAM BOX FOR THE HAMILTON STUDY.

Trial No.	Sample code	Adjusted flexural moduli of rupture, MPa					
		Algoma study			Hamilton study		
		Type 50 cement	Algoma slag	Combined	Type 50 cement	Hamilton slag	Combined
3	512	27.7	----		34.5	----	
4	514	----	32.7		----	30.7	
7	609	----	23.3		----	25.2	
8	615	29.3	----		26.4	----	
11	711	----	48.5		----	49.1	
12	713	56.8	----		50.0	----	
15	810	48.4	----		41.0	----	
16	816	----	67.0		----	78.0	
average		41	43	42	38	46	39
standard deviation		14	19	16	10	24	22

Annex 23

ADJUSTED FLEXURAL MODULI OF RUPTURE AFTER EXPOSURE TO CORROSIVE WATERS FOR PRODUCTS CURED IN SATURATED AIR OR BY IMMERSION

		ADJUSTED FLEXURAL MODULI OF RUPTURE, MPA							
		Algoma study				Hamilton study			
		Type 50 cement		Algoma slag		Type 50 cement		Hamilton slag	
Trial No.	Sample Code	Sea Water	Sulf. Water	Sea Water	Sulf. Water	Sea Water	Sulf. Water	Sea Water	Sulf. Water
1	502	35.1	--	--	--	33.9	--	--	--
2	508	--	--	--	31.9	--	--	--	40.9
3	512	27.7	--	--	--	34.9	--	--	--
4	514	--	--	--	32.7	--	--	--	30.7
5	603	--	--	23.7	--	--	--	24.0	--
6	605	--	27.1	--	--	--	34.2	--	--
7	609	--	--	23.3	--	--	--	25.2	--
8	615	--	29.3	--	--	--	26.9	--	--
9	701	--	--	38.6	--	--	--	45.7	--
10	707	--	36.0	--	--	--	38.3	--	--
11	711	--	--	18.5	--	--	--	49.1	--
12	713	--	56.8	--	--	--	50.0	--	--
13	804	47.5	--	--	--	52.7	--	--	--
14	806	--	--	--	52.0	--	--	--	61.4
15	810	48.4	--	--	--	41.0	--	--	--
16	816	--	--	--	67.0	--	--	--	78.0
average		40	37	34	46	41	37	36	53
standard deviation		10	14	12	17	9	10	13	21
average type 50		38				39			
average slag				40				44	
average sea		37				39			
average sulfated				42				45	
study average		39				42			
grand average				40					

ANNEX 24

TABLEAU: 12: ETUDE DU LAITIER D'ALGOMA STEEL ET DU LAITIER DE HAMILTON.

RANG DE PROBABILITE DES SOMMES DE CONTRASTE DE LA RESISTANCE EN FLEXION AJUSTEE (MRa),APRES EXPOSITION AUX EAUX AGRESSIVES.

ECHANTILLONS: SATURES, SENS DE MARCHE.

RANG No	LAITIER D'ALGOMA STEEL		LAITIER DE HAMILTON	
	PROBABILITE	SOMME DE CONTRASTE	PROBABILITE	SOMME DE CONTRASTE
	1/12+1=	MPa	1/13+1=	MPa
1	0.0769	1.100(X 7)	0.0714	0.537(X 1)
2	0.1538	1.225(X14)	0.1428	(-)1.713(X12)
3	0.2308	1.375(X 6)	0.2143	2.162(X10)
4	0.3077	1.775(X15)	0.2857	2.213(X 7)
5	0.3846	2.200(X 9)	0.3571	2.537(X 6)
6	0.4615	(-)2.900(X12)	0.4286	3.013(X 9)
7	0.5385	3.125(X11)	0.5000	4.463(X 8)
8	0.6154	5.000(X 2)	0.5714	5.438(X14)
9	0.6923	5.225(X 1)	0.6428	6.787(X 2)
10	0.7692	6.425(X 8)	0.7143	6.987(X15)
11	0.8462	7.375(X 4)	0.7857	7.612(X11)
12	0.9231	20.500(X 5)	0.8571	9.963(X 4)
13			0.9286	20.738(X 5)

TABLEAU : 13

ANNEX 25

ETUDE DU LAITIER D'ALGOMA STEEL
ET DU LAITIER DE HAMILTON

COMPARAISON(1) DE LA VARIATION DE RESISTANCE EN FLEXION (%)
APRES EXPOSITION AUX EAUX AGRESSIVES.

ETUDE	LAITIER D'ALGOMA STEEL				LAITIER DE HAMILTON			
TRAITEMENT	AVANT	APRES	ΔMRA	NORMALISE	AVANT	APRES	ΔMRA	NORMALISE
ESSAI NO	CODE	MPa	MPa	%	Δ% MRA +35%	MPa	MPa	%	Δ% MRA +35%
1	502	37.7	35.1	(-) 6.90	28.10	35.8	33.9	(-) 5.31	29.69
2	508	43.1	31.9	(-)25.99	9.01	42.2	40.9	(-) 3.08	31.92
3	512	35.2	27.7	(-)21.31	13.69	31.3	34.5	10.22	45.22
4	514	35.6	32.7	(-) 8.15	26.85	34.2	30.7	(-)10.23	24.77
5	603	26.5	23.7	(-)10.57	24.43	29.6	24.0	(-) 8.92	16.08
6	605	31.1	27.1	(-)12.86	22.14	37.7	34.2	(-) 8.31	26.69
7	609	27.4	23.3	(-)14.96	20.04	26.2	25.2	(-) 4.18	30.82
8	615	32.7	29.3	(-)10.40	24.60	27.5	26.9	(-) 2.18	32.82
9	701	44.4	38.6	(-)13.06	21.94	51.7	45.7	(-)11.61	23.39
10	707	34.5	36.0	4.35	39.35	37.2	38.3	(-) 2.96	37.96
11	711	54.6	48.5	(-)11.17	23.83	60.7	49.1	(-)19.11	15.89
12	713	59.8	56.8	(-) 5.02	29.98	54.6	50.0	(-) 7.58	27.42
13	804	56.5	47.5	(-)15.93	19.07	54.6	52.7	(-) 3.48	31.52
14	806	50.2	52.0	3.59	38.59	56.6	61.4	8.79	43.79
15	810	73.4	48.4	(-)34.06	0.94	62.7	41.0	(-)34.61	0.39
16	816	58.4	67.0	14.73	49.73	68.8	78.0	13.37	48.37
MOYENNE =		43.8	39.1	13.3	24.52	44.4	41.7	10.25	29.17
DEVIATION STANDARD		13.2	12.4	7.9	11.40	13.5	13.9	8.09	11.68

REMARQUE : (1) CETTE COMPARAISON A UNE SIGNIFICATION QUALITATIVE
A CAUSE DE LA DIFFERENCE DE TEMPS DE TRAITEMENT.

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ANNEX 26

TABLEAU 14 : COMPARAISON DES ETUDES DU LAITIER D'ALGOMA STEEL ET DU LAITIER DE HAMILTON.

RANG DE PROBABILITE DES SOMMES DE CONTRASTE DE LA VARIATION DE RESISTANCE EN FLEXION AJUSTEE A (D=1.6) APRES EXPOSITION AUX EAUX AGRESSIVES.

RANG	ETUDE DU LAITIER D'ALGOMA STEEL		ETUDE DU LAITIER DE HALMILTON	
	PROBABILITE	SOMME DE CONTRASTE	PROBABILITE	SOMME DE CONTRASTE
	1/12+1= 0.0769	(%) 0.731 (X12)	1/3+1= 0.0714	(%) 0.172 (X10)
2	0.1538	0.849 (X 6)	0.1428	0.415 (X14)
	0.2308	(-) 1.621 (X 1)	0.2143	(-) 0.723 (X 6)
4	0.3077	(-) 1.996 (X 8)	0.2857	(-) 1.160 (X 5)
5	0.3846	(-) 2.541 (X 4)	0.3571	(-) 1.918 (X 1)
6	0.4615	(-) 2.636 (X15)	0.4286	(-) 2.625 (X12)
7	0.5385	4.569 (X14)	0.5000	3.085 (X 7)
8	0.6154	6.619 (X11)	0.5714	5.575 (X 4)
9	0.6923	6.821 (X 5)	0.6428	7.995 (X15)
10	0.7692	8.241 (X 7)	0.7143	8.123 (X11)
11	0.8462	11.026 (X 2)	0.7857	(-) 9.230 (X 8)
12	0.9231	11.941 (X 9)	0.8571	10.093 (X 2)
13			0.9286	11.495 (X 9)

ANNEX 27

ADJUSTED FLEXURAL MODULI OF RUPTURE COMPARING ALGOMA SLAG AGAINST TYPE 50 CEMENT PRODUCTS EXPOSED TO AGGRESSIVE WATERS FOLLOWED BY FREEZING AND THAWING.

Trial No.	Sample code	Adjusted flexural moduli of rupture, MPa			
		Type 50 cement		Algoma slag	
		Sea Water	sulfated water	Sea water	Sulfated water
1	502	----	----	30.9	----
2	508	----	----	----	40.5
3	512	----	----	33.1	----
4	514	----	----	----	31.8
5	603	27.5	----	----	----
6	605	----	27.5	----	----
7	609	25.1	----	----	----
8	615	----	30.7	----	----
9	701	44.8	----	----	----
10	707	----	35.0	----	----
11	711	58.5	----	----	----
12	713	----	49.0	----	----
13	804	----	----	60.8	----
14	806	----	----	----	46.9
15	810	----	----	55.9	----
16	816	----	----	----	68.2
average		39	36	45	47
standard deviation		17	9	15	16
mean		37		46	

Annex 28

ADJUSTED FLEXURAL MODULI OF RUPTURE COMPARING ALGOMA SLAG AGAINST TYPE 50 CEMENT PRODUCTS EXPOSED TO AGGRESSIVE WATERS FOLLOWED BY MOISTURE SHOCK EXPOSURE.

		Adjusted flexural moduli of rupture, MPa			
		Sea Water exposures		Sulfated water exposures	
Trial No.	Sample Code	Type 50 Cement	Algoma Slag	Type 50 cement	Algoma slag
1	502	--	33.1	--	--
2	508	--	--	--	34.9
3	512	--	27.5	--	--
4	514	--	--	--	28.0
5	603	22.3	--	--	--
6	605	--	--	19.2	--
7	609	25.0	--	--	--
8	615	--	--	27.1	--
9	701	34.1	--	--	--
10	707	--	--	34.2	--
11	711	44.5	--	--	--
12	713	--	--	44.7	--
13	804	--	42.4	--	--
14	806	--	--	--	41.4
15	810	--	47.6	--	--
16	816	--	--	--	70.4
avg		31	38	31	44
std dvn		10	9	11	18
mean		35		37	

Annex 29

ADJUSTED FLEXURAL MODULI OF RUPTURE COMPARING ALGOMA SLAG AGAINST TYPE 50 CEMENT PRODUCTS EXPOSED ONLY TO FREEZING AND THAWING.

TRIAL No.	SAMPLE CODE	ADJUSTED FLEXURAL MODULI OF RUPTURE, MPa	
		TYPE 50 CEMENT	ALGOMA SLAG
1	502		
2	508		38.7
3	512		42.7
4	514		35.2
5	603		35.2
6	605	26.8	
7	609	30.2	
8	615	26.1	
9	701	32.7	
10	707	45.7	
11	711	35.4	
12	713	48.4	
13	804	57.2	
14	806		55.0
15	810		51.1
16	816		72.5
			59.5
avg		38	49
standard deviation		11	13
mean		43	

TABLEAU : 15

ETUDE DU LAITIER D'ALGOMA STEEL.

COMPARAISON DE LA RESISTANCE EN FLEXION, APRES LES TRAITEMENTS DE VIEILLISSEMENT ACCELERE.

ECHANTILLON: SATURE, SENS DE MARCHE.

ESSAI NO:	CODE	EAUX AGRESSIVES (MPa)	EAUX AGRESSIVES + GEL & DEGEL (MPa)	EAUX AGRESSIVES + CHOC HYDRIQUE (MPa)	GEL & DEGEL (MPa)
1	502	35.1	30.9	33.1	38.7
2	508	31.9	40.5	34.9	42.7
3	512	27.7	33.1	27.5	35.2
4	514	32.7	31.8	28.0	35.2
5	603	23.7	27.5	22.3	26.8
6	605	27.1	27.5	19.2	30.2
7	609	23.3	25.1	25.0	26.1
8	615	29.3	30.7	27.1	32.7
9	701	38.6	44.8	34.1	45.7
10	707	36.0	35.0	34.2	35.4
11	711	48.5	58.8	44.5	48.4
12	713	56.8	49.0	44.7	57.2
13	804	47.5	60.8	42.4	55.0
14	806	52.0	46.9	41.4	51.1
15	810	48.4	55.9	47.6	72.5
16	816	67.0	68.2	70.4	59.5
MOYENNE :		39.1	41.7	36.0	63.5
DEVIATION STANDARD		12.4	13.2	12.1	12.8

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TABLEAU : 16

ETUDE : LAITIER D'ALGOMA STEEL.

COMPARAISON DE LA VARIATION DE LA RESISTANCE EN FLEXION AJUSTEE(MRA) APRES LES TRAITEMENTS DE VIEILLISSEMENT ACCELERE.

ECHANTILLONS: SATURES,SENS DE MARCHE.

ESSAI NO:	CODE	EAUX AGRESSIVES		EAUX AGRESSIVES + GEL & DEGEL		EAUX AGRESSIVES + CHOC HYDRIQUE		GEL & DEGEL	
		ΔM (%)	NORMALISE +35% (%)	ΔM (%)	NORMALISE +35% (%)	ΔM (%)	NORMALISE +35% (%)	ΔM (%)	NORMALI +35%
1	502	(-) 6.9	28.1	(-)18.0	17.0	(-)12.2	22.9	(+) 2.7	37.7
2	508	(-)26.0	9.0	(-) 6.0	29.0	(-)19.0	16.1	(-) 0.9	34.1
3	512	(-)21.3	13.7	(-) 6.0	29.0	(-) 0.2	34.9	0.0	35.0
4	514	(-) 8.1	26.9	(-)10.6	24.4	(-)21.2	13.8	(-) 1.1	33.9
5	603	(-)10.6	24.4	(-) 3.8	30.8	(-)15.8	19.3	(+) 1.1	36.1
6	605	(-)12.9	22.1	(-)11.6	23.4	(-)28.7	3.4	(-) 2.9	32.1
7	609	(-)15.0	20.0	(-) 8.4	26.6	(-) 8.8	26.3	(-) 4.8	30.2
8	615	(-)10.4	24.6	(-) 6.1	28.9	(-)17.1	18.0	0.0	35.0
9	701	(-)13.1	21.9	(+) 0.9	35.9	(-)23.2	11.9	(+) 2.9	37.9
10	707	(-)14.3	39.3	(+) 1.4	36.4	(-) 0.9	34.2	(+) 2.6	37.6
11	711	(-)11.2	23.8	(+) 7.7	42.7	(-)18.5	16.6	(-)11.4	23.6
12	713	(-) 5.0	30.0	(-)18.1	16.9	(-)25.3	9.8	(-) 4.3	30.7
13	804	(-)15.9	19.1	(+) 7.6	42.6	(-)25.0	25.1	(-) 2.7	32.3
14	806	(+) 3.6	38.6	(-) 6.6	28.4	(-)17.5	17.6	(+) 1.8	36.8
15	810	(-)34.1	0.9	(-)23.8	11.2	(-)35.1	0.0	(-) 1.2	33.8
16	816	(+)14.7	49.7	(+)16.8	51.8	(+)19.9	55.0	(+) 1.9	36.9

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Annex 32

TABLEAU 17 :

ETUDE DU LAITIER D'ALGOMA STEEL.

RANG DE PROBABILITE DES SOMMES DE CONTRASTE DE LA RESISTANCE EN FLEXION AJUSTEE APRES LES EXPOSITIONS :

- AUX EAUX AGRESSIVES ; ETUDE NO 4.
- AUX EAUX AGRESSIVES + GEL & DEGEL ; ETUDE NO 5.
- AUX EAUX AGRESSIVES + CHOC HYDRIQUE ; ETUDE NO 6.
- AU GEL ET DEGEL ; ETUDE NO 7.

RANG	EAUX AGRESSIVES				GEL + DEGEL	
	PROBABILITE	ETUDE NO.4 (MPa)	ETUDE NO.5 (MPa)	ETUDE NO.6 (MPa)	PROBABILITE	ETUDE NO.7 (MPa)
1	1/12+1= 0.0769	1.100 (I 7)	1.213 (I 7)	(-) 1.225 (II2)	1/11+1= 0.0833	(-) 1.175 (II1)
2	0.1538	1.225 (II4)	1.912 (II1)	1.800 (I 6)	0.1667	(-) 1.350 (II5)
3	0.2308	1.375 (I 6)	2.338 (I 6)	2.150 (I 7)	0.2500	(-) 1.425 (II2)
4	0.3077	1.775 (II5)	(-) 2.362 (II2)	2.275 (II1)	0.3333	1.925 (I 6)
5	0.3846	2.200 (I 9)	2.588 (II4)	2.500 (II5)	0.4167	(-) 2.675 (II4)
6	0.4615	(-)2.900 (II2)	3.938 (II5)	2.600 (I 9)	0.5000	(-) 4.050 (I 9)
7	0.5385	3.125 (II1)	(-) 4.388 (I 9)	3.100 (II4)	0.5833	(-) 4.425 (I 7)
8	0.6154	5.000 (I 2)	4.838 (I 1)	4.550 (II3)	0.6667	5.150 (I 1)
9	0.6923	5.225 (I 1)	5.338 (I 3)	6.650 (I 1)	0.7500	7.450 (I 8)
10	0.7692	6.425 (I 8)	6.263 (I 8)	7.125 (I 8)	0.8333	10.925 (I 4)
11	0.8462	7.375 (I 4)	8.713 (I 4)	9.275 (I 4)	0.9167	19.650 (I 5)
12	0.9231	20.500 (I 5)	21.538 (I 5)	17.775 (I 5)		

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Annex 33

TABLEAU 18 :

ETUDE DU LAITIER D'ALGOMA STEEL.

PROBABILITE DES SOMMES DE CONTRASTE DE LA VARIATION DE RESISTANCE EN FLEXION AJUSTEE APRES LES EXPOSITIONS :

- AUX EAUX AGRESSIVES ; ETUDE NO 4#.
- AUX EAUX AGRESSIVES + GEL & DEGEL ; ETUDE NO 5#.
- AUX AGRESSIVES + CHOC HYDRIQUE ; ETUDE NO 6#.
- AU GEL ET DEGEL ; ETUDE NO 7#.

RANG	EAUX AGRESSIVES				GEL + DEGEL	
	PROBABILITE	ETUDE NO.4#(I)	ETUDE NO.5#(I)	ETUDE NO.6#(I)	PROBABILITE	ETUDE NO.7#(I)
1	1/12+1= 0.0769	0.731 (X12)	0.850 (X 9)	0.563 (X 6)	1/11+1= 0.0833	0.337 (X 6)
2	0.1538	0.849 (X 6)	(-) 2.075 (X 4)	1.938 (X 5)	0.1667	(-) 0.563 (X 5)
3	0.2308	(-) 1.621 (X 1)	2.350 (X12)	2.512 (X12)	0.2500	(-) 0.587 (X14)
4	0.3077	(-) 1.996 (X 8)	(-) 2.500 (X 1)	2.988 (X 1)	0.3333	(-) 0.663 (X15)
5	0.3846	(-) 2.541 (X 4)	2.550 (X 6)	3.537 (X14)	0.4167	0.788 (X11)
6	0.4615	(-) 2.636 (X15)	(-) 2.675 (X 8)	4.462 (X11)	0.5000	(-) 1.712 (X 8)
7	0.5385	4.569 (X14)	3.425 (X15)	(-) 4.838 (X 8)	0.5833	(-) 1.887 (X 7)
8	0.6154	6.619 (X11)	3.900 (X11)	5.013 (X15)	0.6667	2.163 (X 4)
9	0.6923	6.821 (X 5)	5.850 (X 7)	5.488 (X13)	0.7500	2.288 (X 9)
10	0.7692	8.241 (X 7)	6.100 (X 5)	5.738 (X 4)	0.8333	2.863 (X12)
11	0.8462	11.026 (X 2)	9.025 (X14)	8.713 (X 7)	0.9167	(-) 3.188 (X 1)
12	0.9231	11.941 (X 9)	14.425 (X 3)	14.388 (X 9)		

Annex 34

COMPARISON OF ALGOMA SLAG PRODUCTS AFTER 100 FREEZE-THAW CYCLES AGAINST HAMILTON SLAG PRODUCTS AFTER 200 FREEZE-THAW CYCLES

		ALGOMA STUDY AFTER 100 CYCLES			HAMILTON STUDY AFTER 200 CYCLES		
TRIAL No.	SAMPLE CODE	SPALLING	DELAMI-NATION	LOSS IN MASS,%	SPALLING	DELAMI-NATION	LOSS IN MASS,%
1	502	--	--	0.5	light	--	0.9
2	508	--	--	1.6	"	--	0.6
3	512	light	--	1.2	"	unsure	0.8
4	514	--	--	2.0	"	"	1.3
5	603	--	--	3.5	moderate	--	0.5
6	605	--	--	0.9	light	unsure	2.0
7	609	--	--	2.8	"	--	0.2
8	615	light	--	0.8	very light	--	1.1
9	701	"	--	1.3	light	unsure	0.6
10	707	--	--	1.6	"	"	1.2
11	711	--	--	1.9	"	--	1.4
12	713	--	--	2.1	very light	--	0.9
13	804	moderate	--	(-0.4)	light	unsure	0.2
14	806	--	--	1.5	moderate	light	0.0
15	810	light	--	0.7	"	"	0.0
16	816	--	--	2.4	light	--	0.7

Annex 35

TABLEAU : 19

ETUDE DU LAITIER D'ALGOMA STEEL ET DU LAITIER D'HAMILTON.

COMPARAISON: L'ETAT DES PLAQUES APRES L'ESSAI DE GEL ET DEGEL.

ETUDE		LAITIER D'ALGOMA STEEL			LAITIER DE HAMILTON		
		ETAT DES PLAQUES A 100 CYCLES			ETAT DES PLAQUES A 200 CYCLES		
ESSAI NO.	CODE	ECAILLEE	DELAMINEE	VARIATION DE POIDS(%)	ECAILLEE	DELAMINEE	VARIATION DE POIDS(%)
1	502	-	-	0.53	L	-	0.86
2	508	-	-	1.63	L	-	0.59
3	512	L	-	1.17	L	I	0.79
4	514	-	-	1.99	L	I	1.26
5	603	-	-	3.47	M	-	0.53
6	605	-	-	0.86	L	I	1.98
7	609	-	-	2.77	L	-	0.22
8	615	L	-	0.81	TL	-	1.10
9	701	L	-	1.32	L	I	0.57
10	707	-	-	1.55	L	I	1.24
11	711	-	-	1.88	L	-	1.42
12	713	-	-	2.09	TL	-	0.89
13	804	M	-	(-)0.37	L	I	0.18
14	806	-	-	1.47	M	L	0.35
15	810	L	-	0.71	M	-	(-)0.02
16	816	-	-	2.39	L	-	0.74

REMARQUE : L : leger TL : tres leger
I : incertain M : moyen

Annex 36

TABLEAU: 20

ETUDE DU LAITIER D'ALGOMA STEEL ET DU LAITIER DE HAMILTON.

RANG DE PROBABILITE DES SOMMES DE CONTRASTE DU TAUX DE CHANGEMENT DE POIDS NORMALISE APRES LES ESSAIS DE GEL & DEGEL.

RANG No	PROBABILITE	ETUDE DU LAITIER D'ALGOMA STEEL	ETUDE DU LAITIER DE HAMILTON
	1/11+1=	(%)	(%)
1	0.0833	(-) 0.006 (X 6)	0.011 (X 4)
2	0.1667	(-) 0.069 (X15)	(-) 0.096 (X15)
3	0.2500	(-) 0.134 (X 7)	0.159 (X 8)
4	0.3333	(-) 0.274 (X 5)	(-) 0.166 (X14)
5	0.4167	0.331 (X12)	(-) 0.181 (X 9)
6	0.5000	0.356 (X 8)	0.184 (X12)
7	0.5833	0.419 (X 1)	(-) 0.246 (X 5)
8	0.6667	(-) 0.426 (X11)	(-) 0.319 (X 6)
9	0.7500	(-) 0.654 (X 4)	0.366 (X11)
10	0.8333	0.826 (X 9)	0.389 (X 7)
11	0.9167	1.196 (X14)	(-) 0.401 (X 4)

Annex 37

HARKORT TRIALS FOR THE ALGOMA SLAG STUDY

TEMPERATURE	TYPE 50 CEMENT PRODUCTS	ALGOMA SLAG PRODUCTS
100°C	no change	no change
120	no change	no change
140	no change	no change
160	light colored specimens were slightly yellowed	light colores specimens were slightly yellowed
180	"	"
200	products containing fly ash darkened Fibres appeared at the surface of samples coded 701, 711, 713	products containing fly ash darkened Fibres appeared at the surface of samples coded 804 and 810
210	The yellow discoloration grew darker	The yellow discoloration grew darker
220	No change	No change
230	"	"
240	----	Samples coded 804 showed signs of spalling
250	The yellow discoloration grew darker	The yellow discoloration grew darker
260	Light spalling on samples coded 713	Light spalling samples coded 804 and 810
270	no change	no change
280	Fibres appeared at the surface of samples codes 603, 615 and 707 signs of spalling on samples coded 605, 701 and 711	Fibres appeared at the surface of samples coded 508, 512, 514 and 816
	Spalling on samples coded 713	Spalling on samples coded 804 and 810
	Excellent condition for samples coded 609	Excellent condition for samples coded 502 and 806

TABLEAU 21 : Comparaison des resultats des essais Harkort des etudes du laitier d'Algoma Steel et du laitier de Hamilton.

TEMPERATURE °C	ETUDE DU LAITIER D'ALGOMA STEEL	ETUDE DU LAITIER DE HAMILTON
100	Pas de changement de l'etat des plaques.	Pas de changement de l'etat des plaques.
120	- id -	- id -
140	- id -	- id -
160	Plaques de couleur clair, leger jaunissement.	Plaques de couleur clair, leger jaunissement. -- arret de l'experience
180	- id -	
200	Degradation de couleur gris fonce des plaques realisees avec la cendre volante. Apparition de fibres sur la surface des plaques: 701, 711, 713, 804, 810	
210	Couleur jaune devient foncee.	
220	Pas de changement.	
230	- id -	
240	Plaques 804 ont des signes d'ecaillage.	
250	Couleur jaune devient plus foncee.	
260	Ecailles legerement :713, 804, 810.	
270	Pas de changement.	
280	Bonnes plaques : 502, 609, 806. Apparition des fibres sur la surface :508, 512, 514, 603, 615, 707, 816. Signe d'ecaillage : 605, 701, 711. Ecaillees : 713, 804, 810.	

Annex 39

DENSITY OF ALL PRODUCTS (PRESSED AND UNPRESSED) PRIOR TO EXPOSURE

TRIAL No.	SAMPLE CODE	ALGOMA STUDY TYPE 50 CEMENT	ALGOMA STUDY ALGOMA SLAG	HAMILTON STUDY TYPE 50 CEMENT	HAMILTON STUDY HAMILTON SLAG
1	502*	--	1.686	--	1.731
2	508	--	1.401	--	1.578
3	512*	--	1.954	--	1.876
4	514	--	1.382	--	1.452
5	603*	1.893	--	1.995	--
6	605	1.493	--	1.529	--
7	609*	1.685	--	1.718	--
8	615	1.768	--	1.839	--
9	701	1.409	--	1.478	--
10	707*	1.732	--	1.739	--
11	711	1.228	--	1.201	--
12	713*	1.820	--	1.771	--
13	804	--	1.234	--	1.245
14	806*	--	1.710	--	1.685
15	810	--	1.293	--	1.353
16	816*	--	1.490	--	1.490
average		1.63	1.52	1.66	1.55
standard deviation		0.23	0.24	0.25	0.21
mean		1.57		1.60	

*Pressed products

Annex 40

DENSITY OF PRESSED PRODUCTS PRIOR TO EXPOSURE

TRIAL NO.	SAMPLE CODE	ALGOMA STUDY TYPE 50 CEMENT	ALGOMA STUDY ALGOMA SLAG	HAMILTON STUDY TYPE 50 CEMENT	HAMILTON STUDY ALGOMA SLAG
1	502	--	1.686	--	1.731
3	512	--	1.954	--	1.876
5	603	1.893	--	1.995	--
7	609	1.685	--	1.718	--
10	707	1.732	--	1.739	--
12	713	1.820	--	1.771	--
14	806	--	1.710	--	1.685
16	816	--	1.490	--	1.490
average		1.7825	1.710	1.8045	1.6955
standard deviation		0.0925	0.1900	0.1289	0.1594
mean		1.7463		1.7500	

Annex 41

DENSITY OF UNPRESSED PRODUCTS PRIOR TO EXPOSURE

TRIAL NO.	SAMPLE CODE	ALGOMA STUDY TYPE 50 CEMENT	ALGOMA STUDY ALGOMA SLAG	HAMILTON STUDY TYPE 50 CEMENT	HAMILTON STUDY ALGOMA SLAG
2	508	--	1.401	--	1.578
4	514	--	1.382	--	1.452
6	605	1.493	--	1.529	--
8	615	1.768	--	1.839	--
9	701	1.409	--	1.478	--
11	711	1.228	--	1.201	--
13	804	--	1.234	--	1.245
15	810	--	1.293	--	1.353
average		1.4745	1.3275	1.5118	1.4070
standard deviation		0.2247	0.0781	0.2615	0.1419
mean		1.401		1.459	

Annex 42

TABLEAU 22: ETUDE DU LAITIER D'ALGOMA STEEL ET DU LAITIER DE HAMILTON.

COMPARAISON DE LA DENSITE DES PLAQUES, AVANT ET APRES EXPOSITION AUX EAUX AGRESSIVES.

ETUDE		LAITIER D'ALGOMA STEEL			LAITIER DE HAMILTON			
ESSAI No	CODE	AVANT	APRES	ΔD (%)	AVANT	APRES	ΔD (%)	
1	502*	1.686	1.747	3.67	1.731	1.811	4.6	**
2	508	1.401	1.482	5.75	1.578	1.632	3.4	
3	512*	1.954	2.004	2.56	1.876	1.926	2.7	
4	514	1.382	1.455	5.27	1.452	1.603	10.4	**
5	603*	1.893	1.943	2.63	1.995	2.126	6.6	**
6	605	1.493	1.527	2.23	1.529	1.590	4.0	
7	609*	1.685	1.751	3.95	1.718	1.784	3.9	
8	615	1.768	1.834	3.75	1.939	1.916	4.2	**
9	701	1.409	1.477	4.84	1.478	1.470	-0.5	**
10	707*	1.732	1.776	2.52	1.739	1.778	2.2	
11	711	1.228	1.337	8.95	1.201	1.405	17.0	
12	713*	1.820	1.848	1.54	1.771	1.888	6.6	**
13	804	1.234	1.325	7.39	1.245	1.284	3.1	**
14	806*	1.710	1.767	3.35	1.685	1.752	4.0	
15	810	1.293	1.383	6.96	1.353	1.497	10.6	
16	816*	1.490	1.542	3.49	1.490	1.551	4.1	**
MOYENNE		1.574	1.637	4.30	1.605	1.688	5.4	
DEVIATION STANDARD		0.228	0.213	2.01	0.220	0.216	4.0	

REMARQUE: * PLAQUE COMPRIMEE
** TRAITEMENT DYNAMIQUE

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Annex 43

TABLEAU: 23

ETUDE DU LAITIER D'ALGOMA STEEL ET DU LAITIER DE HAMILTON.

RANG DE PROBABILITE DES SOMMES DE CONTRASTE DE DENSITE AVANT EXPOSITION AUX EAUX AGRESSIVES.

RANG No	PROBABILITE	ETUDE DU LAITIER D'ALGOMA STEEL	ETUDE DU LAITIER DE HAMILTON
	1/11+1=		
1	0.0833	(-) 0.01 (X 6)	0.00 (X11)
2	0.1667	0.01 (X 1)	0.00 (X 6)
3	0.2500	0.01 (X12)	0.02 (X12)
4	0.3333	(-) 0.03 (X15)	(-) 0.03 (X 1)
5	0.4167	0.04 (X11)	(-) 0.04 (X15)
6	0.5000	(-) 0.07 (X 8)	(-) 0.05 (X 8)
7	0.5833	(-) 0.10 (X14)	(-) 0.06 (X14)
8	0.6667	(-) 0.11 (X 4)	(-) 0.11 (X 4)
9	0.7500	(-) 0.16 (X 7)	(-) 0.18 (X 7)
10	0.8333	(-) 0.17 (X 5)	(-) 0.22 (X 5)
11	0.9167	0.34 (X 9)	0.29 (X 9)

Annex 44

DENSITY OF ALL PRODUCTS (PRESSED AND UNPRESSED) AFTER EXPOSURE

TRIAL NO.	SAMPLE CODE	ALGOMA STUDY TYPE 50 CEMENT	ALGOMA STUDY ALGOMA SLAG	HAMILTON STUDY TYPE 50 CEMENT	HAMILTON STUDY ALGOMA SLAG
1	502*	--	1.747	--	1.811
2	508	--	1.482	--	1.632
3	512*	--	2.004	--	1.926
4	514	--	1.455	--	1.603
5	603*	1.943	--	2.126	--
6	605	1.527	--	1.590	--
7	609*	1.751	--	1.784	--
8	615	1.834	--	1.916	--
9	701	1.477	--	1.470	--
10	707*	1.776	--	1.778	--
11	711	1.337	--	1.405	--
12	713*	1.848	--	1.888	--
13	804	--	1.325	--	1.284
14	806*	--	1.767	--	1.752
15	810	--	1.383	--	1.497
16	816*	--	1.542	--	1.551
average		1.687	1.588	1.745	1.632
standard deviation		0.213	0.231	0.231	0.200
mean		1.637		1.688	

* pressed products

Annex 45

DENSITIES OF PRESSED PRODUCTS AFTER EXPOSURE TO AGGRESSIVE WATERS

TRIAL NO.	SAMPLE CODE	ALGOMA STUDY TYPE 50 CEMENT	ALGOMA STUDY ALGOMA SLAG	HAMILTON STUDY TYPE 50 CEMENT	HAMILTON STUDY ALGOMA SLAG
1	502	--	1.747	--	1.811
3	512	--	2.004	--	1.926
5	603	1.943	--	2.126	--
7	609	1.751	--	1.784	--
10	707	1.776	--	1.778	--
12	713	1.848	--	1.888	--
14	806	--	1.767	--	1.752
16	816	--	1.542	--	1.551
average		1.830	1.765	1.894	1.760
standard deviation		0.45	0.19	0.16	0.16
mean		1.797		1.827	

Annex 46

DENSITY OF UNPRESSED PRODUCTS AFTER EXPOSURE TO AGGRESSIVE WATERS

TRIAL NO.	SAMPLE CODE	ALGOMA STUDY		HAMILTON STUDY	
		TYPE 50 CEMENT	ALGOMA SLAG	TYPE 50 CEMENT	ALGOMA SLAG
2	508	--	1.482	--	1.632
4	514	--	1.455	--	1.603
6	605	1.527	--	1.510	--
8	615	1.834	--	1.916	--
9	701	1.477	--	1.470	--
11	711	1.337	--	1.405	--
13	804	--	1.325	--	1.284
15	810	--	1.383	--	1.497
average		1.544	1.411	1.595	1.504
standard deviation		0.21	0.07	0.23	0.16
mean		1.478		1.550	

Annex 47

DENSITIES OF PRODUCTS AFTER EXPOSURE TO SEA WATER OR TO SULFATED WATER

TRIAL NO.	SAMPLE CODE	ALGOMA STUDY				HAMILTON STUDY			
		TYPE 50 CEMENT		ALGOMA SLAG		TYPE 50 CEMENT		HAMILTON SLAG	
		sea	sulfated	sea	sulfated	sea	sulfated	sea	sulfated
1	502	--	--	1.747	--	--	--	1.811	--
2	508	--	--	--	1.482	--	--	--	1.632
3	512	--	--	2.004	--	--	--	1.926	--
4	514	--	--	--	1.455	--	--	--	1.603
5	603	1.943	--	--	--	2.126	--	--	--
6	605	--	1.527	--	--	--	1.590	--	--
7	609	1.751	--	--	--	1.784	--	--	--
8	615	--	1.834	--	--	--	1.916	--	--
9	701	1.477	--	--	--	1.477	--	--	--
10	707	--	1.776	--	--	--	1.778	--	--
11	711	1.337	--	--	--	1.405	--	--	--
12	713	--	1.848	--	--	--	1.888	--	--
13	804	--	--	1.325	--	--	--	1.284	--
14	806	--	--	--	1.767	--	--	--	1.752
15	810	--	--	1.383	--	--	--	1.417	--
16	816	--	--	--	1.542	--	--	--	1.551
average		1.627	1.746	1.627	1.562	1.698	1.794	1.630	1.485
Standard deviation		0.27	0.15	0.33	0.14	0.33	0.15	0.29	0.33
mean		1.687		1.594		1.746		1.557	

TABLEAU: 24: ETUDE DU LAITIER D'ALGOMA STEEL ET DU LAITIER DE HAMILTON.

RANG DE PROBABILITE DES SOMMES DE CONTRASTE DE DENSITE
APRES EXPOSITION AUX EAUX AGRESSIVES.

RANG No	LAITIER D'ALGOMA STEEL		LAITIER DE HAMILTON	
	PROBABILITE	SOMME DE CONTRASTE	PROBABILITE	SOMME DE CONTRASTE
	1/12+1=		1/13+1=	
1	0.0769	0.0 (X12)	0.0714	(-) 0.00(X 6)
2	0.1538	0.01 (X 6)	0.1428	(-) 0.00(X 8)
3	0.2308	0.01 (X 1)	0.2143	0.01(X12)
4	0.3077	0.03 (X 2)	0.2857	0.02(X 1)
5	0.3846	0.03 (X11)	0.3571	(-)0.02(X11)
6	0.4615	(-)0.04 (X15)	0.4286	0.04(X10)
7	0.5385	(-)0.07 (X 8)	0.5000	(-)0.05(X14)
8	0.6154	(-)0.09 (X14)	0.5714	0.05(X 2)
9	0.6923	(-)0.10 (X 4)	0.6428	(-)0.10(X15)
10	0.7692	(-)0.16 (X 7)	0.7143	(-)0.11(X 4)
11	0.8462	(-)0.16 (X 5)	0.7857	(-)0.18(X 7)
12	0.9231	0.32 (X 9)	0.8571	(-)0.22(X 5)
13			0.9286	0.28(X 9)

ANNEX 49

TABLEAU: 25: ETUDE DU LAITIER D'ALGOMA STEEL ET DU LAITIER DE HAMILTON.

RANG DE PROBABILITE DES SOMMES DE CONTRASTE DE L'AUGMENTATION DE DENSITE APRES EXPOSITION AUX EAUX AGRESSIVES.

RANG No	LAITIER D'ALGOMA STEEL		LAITIER DE HAMILTON	
	PROBABILITE	SOMME DE CONTRASTE	PROBABILITE	SOMME DE CONTRASTE
	1/12+1=	(%)	1/13+1=	(%)
1	0.0769	(-)0.169 (X 6)	0.0714	(-)0.136 (X 4)
2	0.1538	0.199 (X 8)	0.1428	(-)0.739 (X 6)
3	0.2308	(-)0.396 (X11)	0.2143	(-)0.836 (X11)
4	0.3077	0.511 (X 1)	0.2857	(-)0.836 (X12)
5	0.3846	(-)0.669 (X15)	0.3571	0.911 (X 5)
6	0.4615	0.761 (X 7)	0.4286	(-)1.089 (X10)
7	0.5385	0.951 (X14)	0.5000	(-)1.139 (X 2)
8	0.6154	(-)0.981 (X12)	0.5714	1.631 (X14)
9	0.6923	1.004 (X 4)	0.6428	1.461 (X 7)
10	0.7692	1.154 (X 5)	0.7143	(-)2.200 (X 9)
11	0.8462	(-)1.600 (X 2)	0.7857	3.361 (X 8)
12	0.9231	(-)2.700 (X 9)	0.8571	4.014 (X 1)
13			0.9286	(-)4.036 (X15)

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ANNEX 50

POROSITY OF ALL PRODUCTS BEFORE EXPOSURE TO AGGRESSIVE WATERS, %.

		Algoma study		Hamilton study	
Trial No.	Sample code	Type 50 cement	Algoma slag	Type 50 cement	Hamilton slag
1	502*	----	16.6	----	17.5
2	508	----	28.7	----	21.5
3	512*	----	13.9	----	14.0
4	514	----	30.7	----	26.3
5	603*	13.4	----	11.7	----
6	605	25.2	----	22.1	----
7	609*	20.0	----	15.5	----
8	615	18.6	----	15.3	----
9	701	31.5	----	22.2	----
10	707*	16.5	----	16.9	----
11	711	40.3	----	40.6	----
12	713*	16.4	----	14.5	----
13	804	----	38.1	----	30.5
14	806*	----	19.1	----	21.5
15	810	----	37.9	----	32.8
16	816*	----	27.7	----	24.3
average		22.7	26.6	19.9	16.0
standard deviation		9.1	9.3	9.1	11.0
mean		24.7		17.9	

* Pressed products

ANNEX 51

POROSITY OF PRESSED PRODUCTS ONLY PRIOR TO EXPOSURE TO AGGRESSIVE WATERS, %.

		Algoma study		Hamilton study	
Trial No.	Sample code	Type 50 cement	Algoma slag	Type 50 cement	Hamilton slag
1	502	----	16.6	----	17.5
3	512	----	13.9	----	14.0
5	603	13.4	----	11.7	----
7	609	20.0	----	15.5	----
10	707	16.5	----	16.9	----
12	713	16.4	----	14.5	----
14	806	----	19.1	----	21.5
16	816	----	27.7	----	24.3
average		13.7	19.3	16.1	19.3
standard deviation		8.3	6.0	1.4	4.5
mean		16.5		17.7	

ANNEX 52

POROSITY OF UNPRESSED PRODUCTS ONLY PRIOR TO EXPOSURE TO AGGRESSIVE WATERS, %.

		Algoma study		Hamilton study	
Trial No.	Sample code	Type 50 cement	Algoma slag	Type 50 cement	Hamilton slag
2	508	----	28.7	----	21.5
4	514	----	30.7	----	26.3
6	605	25.2	----	22.1	----
8	615	18.6	----	15.3	----
9	701	31.5	----	22.2	----
11	711	40.3	----	40.6	----
13	804	----	38.1	----	30.5
15	810	----	37.9	----	32.8
average		28.9	33.9	25.1	27.8
standard deviation		9.2	4.9	10.9	5.0
mean		31.4		26.4	

ANNEX 53

TABLEAU 25: ETUDE DU LAITIER D'ALGOMA STEEL ET DU LAITIER DE HAMILTON.

COMPARAISON DE LA POROSITE DES PLAQUES, AVANT ET APRES EXPOSITION AUX EAUX AGRESSIVES.

ETUDE		LAITIER D'ALGOMA STEEL			LAITIER DE HAMILTON			
ESSAI No	CODE	AVANT (%)	APRES (%)	ΔP (%)	AVANT (%)	APRES (%)	ΔP (%)	
1	502*	16.6	5.6	-11.0	17.5	15.0	-2.5	**
2	508	28.7	23.7	-5.0	21.5	5.2	-16.3	
3	512*	13.9	7.1	-6.8	14.0	3.2	-10.8	
4	514	30.7	23.1	-7.6	26.3	17.5	-8.8	**
5	603*	13.4	5.8	-7.6	11.7	5.8	-5.9	**
6	605	25.2	11.9	-13.3	22.1	5.1	-17.0	
7	609*	20.0	6.8	-13.2	15.5	2.6	-12.9	
8	615	18.6	10.5	-8.1	15.3	10.4	-4.9	**
9	701	31.5	26.4	-5.1	22.2	25.4	3.2	**
10	707*	16.5	4.6	-11.9	16.9	2.7	-14.2	
11	711	40.3	32.9	-7.4	40.6	31.5	-9.1	
12	713*	16.4	8.0	-8.4	14.5	11.5	-3.0	**
13	804	38.1	27.7	-10.4	30.5	32.7	2.2	**
14	806*	19.1	9.2	-9.9	21.5	3.6	-17.9	
15	810	37.9	27.1	-10.8	32.8	25.9	-6.9	
16	816*	27.7	15.1	-12.6	24.3	20.7	-3.6	**
MOYENNE		24.7	15.3	-9.3	21.7	13.7	-8.0	
DEVIATION STANDARD		8.8	9.4	2.6	7.6	10.3	6.3	

REMARQUE: * PLAQUE COMPRIMEE
** TRAITEMENT DYNAMIQUE

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ANNEX 54

POROSITY OF ALL PRODUCTS AFTER EXPOSURE TO AGGRESSIVE WATERS.

		Algoma study		Hamilton study	
Trial No.	Sample code	Type 50 cement	Algoma slag	Type 50 cement	Hamilton slag
1	502	----	5.6	----	15.0
2	508	----	23.7	----	5.2
3	512	----	7.1	----	3.2
4	514	----	23.1	----	17.5
5	603	5.8	----	5.8	----
6	605	11.9	----	5.1	----
7	609	6.8	----	2.6	----
8	615	10.5	----	10.4	----
9	701	26.4	----	25.4	----
10	707	4.6	----	2.7	----
11	711	32.9	----	31.5	----
12	713	8.0	----	11.5	----
13	804	----	27.7	----	32.7
14	806	----	9.2	----	3.6
15	810	----	27.1	----	25.9
16	816	----	15.9	----	20.7
average		13	17	13	12
standard deviation		10	9	11	12
mean		15		13	

* Pressed products

ANNEX 55

POROSITY OF PRESSED PRODUCTS ONLY AFTER EXPOSURE TO AGGRESSIVE WATERS.

		Algoma study		Hamilton study	
Trial No.	Sample code	Type 50 cement	Algoma slag	Type 50 cement	Hamilton slag
1	502	----	5.6	----	15.0
3	512	----	7.1	----	3.2
5	603	5.8	----	5.8	----
7	609	6.8	----	2.6	----
10	707	4.6	----	2.7	----
12	713	8.0	----	11.5	----
14	806	----	9.2	----	3.6
16	816	----	15.1	----	20.7
average		6.3	9.3	5.7	10.6
standard deviation		1.4	4.2	4.2	8.7
mean		7.8		8.1	

ANNEX 56

POROSITY OF UNPRESSED PRODUCTS AFTER EXPOSURE TO AGGRESSIVE WATERS.

		Algoma study		Hamilton study	
Trial No.	Sample code	Type 50 cement	Algoma slag	Type 50 cement	Hamilton slag
2	508	----	23.7	----	5.2
4	514	----	23.1	----	17.5
6	605	11.9	----	5.1	----
8	615	10.5	----	10.4	----
9	701	26.4	----	25.4	----
11	711	32.9	----	31.5	----
13	804	----	27.7	----	32.7
15	810	----	27.1	----	25.9
average		20.4	25.4	18.1	20.3
standard deviation		11	2.3	12	12
mean		22.9		19.2	

ANNEX 57

POROSITY OF ALL THE PRODUCTS AFTER EXPOSURE TO SEA WATER.

		Algoma study		Hamilton study	
Trial No.	Sample code	Type 50 cement	Algoma slag	Type 50 cement	Hamilton slag
1	502	----	5.6	----	15.5
3	512	----	7.1	----	3.2
5	603	5.8	----	5.8	----
7	609	6.8	----	2.6	----
9	701	26.4	----	25.4	----
11	711	32.9	----	31.5	----
13	804	----	27.7	----	32.7
15	810	----	27.1	----	25.9
average		18.0	16.9	16.4	19.2
standard deviation		14	12	14	13
mean		17.4		17.8	

ANNEX 58

POROSITY OF ALL THE PRODUCTS AFTER EXPOSURE TO SULFATED WATER.

		Algoma study		Hamilton study	
Trial No.	Sample code	Type 50 cement	Algoma slag	Type 50 cement	Hamilton slag
2	508	----	23.7	----	5.2
4	514	----	23.1	----	17.5
6	605	11.9	----	5.1	----
8	615	10.5	----	10.4	----
10	707	4.6	----	2.7	----
14	806	----	9.2	----	3.6
16	816	----	15.1	----	20.7
average		8.8	12.5	7.4	11.8
standard deviation		3.2	8.7	4.2	8.6
mean		10.6		9.6	

ANNEX . 59

TABLEAU: 24: ETUDE DU LAITIER D'ALGOMA STEEL ET DU LAITIER DE HAMILTON.

RANG DE PROBABILITE DES SOMMES DE CONTRASTE DE DENSITE APRES EXPOSITION AUX EAUX AGRESSIVES.

RANG No	LAITIER D'ALGOMA STEEL		LAITIER DE HAMILTON	
	PROBABILITE	SOMME DE CONTRASTE	PROBABILITE	SOMME DE CONTRASTE
	1/12+1=		1/13+1=	
1	0.0769	0.0 (X12)	0.0714	(-) 0.00(X 6)
2	0.1538	0.01 (X 6)	0.1428	(-) 0.00(X 8)
3	0.2308	0.01 (X 1)	0.2143	0.01(X12)
4	0.3077	0.03 (X 2)	0.2857	0.02(X 1)
5	0.3846	0.03 (X11)	0.3571	(-)0.02(X11)
6	0.4615	(-)0.04 (X15)	0.4286	0.04(X10)
7	0.5385	(-)0.07 (X 8)	0.5000	(-)0.05(X14)
8	0.6154	(-)0.09 (X14)	0.5714	0.05(X 2)
9	0.6923	(-)0.10 (X 4)	0.6428	(-)0.10(X15)
10	0.7692	(-)0.16 (X 7)	0.7143	(-)0.11(X 4)
11	0.8462	(-)0.16 (X 5)	0.7857	(-)0.18(X 7)
12	0.9231	0.32 (X 9)	0.8571	(-)0.22(X 5)
13			0.9286	0.28(X 9)

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ANNEX 60

TABLEAU: 25: ETUDE DU LAITIER D'ALGOMA STEEL ET DU LAITIER DE HAMILTON.

RANG DE PROBABILITE DES SOMMES DE CONTRASTE DE L'AUGMENTATION DE DENSITE APRES EXPOSITION AUX EAUX AGRESSIVES.

RANG No	LAITIER D'ALGOMA STEEL		LAITIER DE HAMILTON	
	PROBABILITE	SOMME DE CONTRASTE	PROBABILITE	SOMME DE CONTRASTE
	1/12+1=	(%)	1/13+1=	(%)
1	0.0769	(-)0.169 (X 6)	0.0714	(-)0.136 (X 4)
2	0.1538	0.199 (X 8)	0.1428	(-)0.739 (X 6)
3	0.2308	(-)0.396 (X11)	0.2143	(-)0.836 (X11)
4	0.3077	0.511 (X 1)	0.2857	(-)0.836 (X12)
5	0.3846	(-)0.669 (X15)	0.3571	0.911 (X 5)
6	0.4615	0.761 (X 7)	0.4286	(-)1.089 (X10)
7	0.5385	0.951 (X14)	0.5000	(-)1.139 (X 2)
8	0.6154	(-)0.981 (X12)	0.5714	1.631 (X14)
9	0.6923	1.004 (X 4)	0.6428	1.461 (X 7)
10	0.7692	1.154 (X 5)	0.7143	(-)2.200 (X 9)
11	0.8462	(-)1.600 (X 2)	0.7857	3.361 (X 8)
12	0.9231	(-)2.700 (X 9)	0.8571	4.014 (X 1)
13			0.9286	(-)4.036 (X15)

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ANNEX. 61

TABLEAU 25: ETUDE DU LAITIER D'ALGOMA STEEL ET DU LAITIER DE HAMILTON.

COMPARAISON DE LA POROSITE DES PLAQUES, AVANT ET APRES EXPOSITION AUX EAUX AGRESSIVES.

ETUDE		LAITIER D'ALGOMA STEEL			LAITIER DE HAMILTON			
ESSAI No	CODE	AVANT (%)	APRES (%)	ΔP (%)	AVANT (%)	APRES (%)	ΔP (%)	
1	502*	16.6	5.6	-11.0	17.5	15.0	-2.5	**
2	508	28.7	23.7	-5.0	21.5	5.2	-16.3	
3	512*	13.9	7.1	-6.8	14.0	3.2	-10.8	
4	514	30.7	23.1	-7.6	26.3	17.5	-8.8	**
5	603*	13.4	5.8	-7.6	11.7	5.8	-5.9	**
6	605	25.2	11.9	-13.3	22.1	5.1	-17.0	
7	609*	20.0	6.8	-13.2	15.5	2.6	-12.9	
8	615	18.6	10.5	-8.1	15.3	10.4	-4.9	**
9	701	31.5	26.4	-5.1	22.2	25.4	3.2	**
10	707*	16.5	4.6	-11.9	16.9	2.7	-14.2	
11	711	40.3	32.9	-7.4	40.6	31.5	-9.1	
12	713*	16.4	8.0	-8.4	14.5	11.5	-3.0	**
13	804	38.1	27.7	-10.4	30.5	32.7	2.2	**
14	806*	19.1	9.2	-9.9	21.5	3.6	-17.9	
15	810	37.9	27.1	-10.8	32.8	25.9	-6.9	
16	816*	27.7	15.1	-12.6	24.3	20.7	-3.6	**
MOYENNE		24.7	15.3	-9.3	21.7	13.7	-8.0	
DEVIATION STANDARD		8.8	9.4	2.6	7.6	10.3	6.3	

REMARQUE: * PLAQUE COMPRIMEE
** TRAITEMENT DYNAMIQUE

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ANNEX 62

DECREASES IN POROSITY DUE TO EXPOSURE TO THE AGGRESSIVE WATERS FOR THE SLAG PRODUCTS ONLY, %

		Algoma study			Hamilton study		
Trial No.	Sample code	Before expos.%	After expos. %	ΔP %	Before expos. %	After expos. %	ΔP %
1	502*	16.6	5.6	11.0	17.5	15.0	2.5
2	508	28.7	23.7	5.0	21.5	5.2	16.3
3	512*	13.9	7.1	6.8	14.0	3.2	10.8
4	514	30.7	23.1	7.6	26.3	17.5	8.8
13	804	38.1	27.7	10.4	30.5	32.7	(-2.2)
14	806*	19.1	9.2	9.9	21.5	3.6	17.9
15	810	37.9	27.1	10.8	32.8	25.9	6.9
16	816*	27.7	15.1	12.6	24.3	20.7	3.6
average		26.6	17.3	9.3	23.6	15.5	12.2
standard deviation		9.3	9.2	2.5	6.3	10.9	7.9
mean		22.0			19.5		

ANNEX 63

TABLEAU: 27

ETUDE DU LAITIER D'ALGOMA STEEL ET DU LAITIER DE HAMILTON.

RANG DE PROBABILITE DES SOMMES DE CONTRASTE DE POROSITE AVANT EXPOSITION AUX EAUX AGRESSIVES.

RANG No	PROBABILITE	ETUDE DU LAITIER D'ALGOMA STEEL	ETUDE DU LAITIER DE HAMILTON
	1/11+1=	(%)	(%)
1	0.0833	(-) 0.125 (X12)	0.025 (X 6)
2	0.1667	0.675 (X 6)	(-) 0.825 (X12)
3	0.2500	1.050 (X15)	0.975 (X11)
4	0.3333	(-) 1.100 (X11)	(-) 2.250 (X15)
5	0.4167	2.050 (X 1)	2.425 (X 1)
6	0.5000	2.225 (X 8)	2.500 (X14)
7	0.5833	3.525 (X14)	2.850 (X 8)
8	0.6667	3.850 (X 4)	3.700 (X 4)
9	0.7500	4.450 (X 7)	5.025 (X 7)
10	0.8333	7.550 (X 5)	7.424 (X 5)
11	0.9167	(-)13.425 (X 9)	(-) 9.425 (X 9)

ANNEX : 64

TABLEAU : 28: ETUDE DU LAITIER D'ALGOMA STEEL ET DU LAITIER DE HAMILTON.

RANG DE PROBABILITE DES SOMMES DE CONTRASTE DE DE POROSITE APRES EXPOSITION AUX EAUX AGRESSIVES.

RANG No	LAITIER D'ALGOMA STEEL		LAITIER DE HAMILTON	
	PROBABILITE	SOMME DE CONTRASTE	PROBABILITE	SOMME DE CONTRASTE
	1/12+1=	(%)	1/13+1=	(%)
1	0.0769	(-) 0.412 (X12)	0.0714	(-) 0.650 (X 6)
2	0.1538	0.963 (X15)	0.1428	0.725 (X14)
3	0.2308	(-) 1.013 (X11)	0.2143	(-) 0.750 (X15)
4	0.3077	1.263 (X 7)	0.2857	(-) 0.775 (X12)
5	0.3846	1.837 (X 8)	0.3571	1.375 (X11)
6	0.4615	1.962 (X 1)	0.4286	2.825 (X 8)
7	0.5385	(-) 2.188 (X 6)	0.5000	3.475 (X 1)
8	0.6154	3.938 (X 4)	0.5714	3.600 (X 4)
9	0.6923	(-) 4.163 (X 2)	0.6428	4.600 (X 7)
10	0.7692	5.063 (X14)	0.7143	7.400 (X10)
11	0.8462	7.087 (X 5)	0.7857	(-) 8.175 (X 2)
12	0.9231	(-)15.137 (X 9)	0.8571	(-)11.075 (X 9)
13			0.9286	11.150 (X 5)

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APPENDIX A

APPENDIX A

ACTUAL AND FORECAST EXPENDITURES AT THE END OF APRIL 1987

MONTH	ITEM	ACTUAL EXPENDITURES	FORECAST EXPENDITURES
October 86	Procurement	0	0.78
	Fabrication	0	1.12
	Subtotal	0	1.90
November 86	Fabrication		1.13
	Exposure SE & Su	0	0.29
	Exposure freeze-thaw	0	0.14
	Exposure moisture shock	0	0.14
	Subtotal	0	1.70
December 86	Exposure SE & SU	0	0.30
	Exposure freeze-thaw	0	0.15
	Exposure moisture shock	0	0.14
	Combined exposure	0	0.26
	Harkort testing	0	0.20
	Moisture shock	0	0.20
	Freezing and thawing	0	0.20
	Subtotal	0	1.45
January 87	Combined exposure	0	0.30
	Harkort testing	0	0.20
	Moisture shock	0	0.20
	Freezing and thawing	0	0.20
	Subtotal	0	0.90

February	Harkort testing	0	0.20
	Moisture shock	0	0.20
	Freezing and thawing	0	0.20
	Testing	0	0.20
	Subtotal	0	0.80
March 87	Procurement	0.67	0
	Fabrication	0.965	0
	Testing	0	0.20
	Report	0	1.28
	Subtotal	1.635	1.48
April 87	Procurement	0.45	0
	Fabrication	4.78	0
	Exposure SE & SU	1.366	0
	Subtotal	6.596	0
May 87	Exposure SE & SU	no charge	0
	Exposure to freeze-thaw	-	0
	Exposure to moisture shock	-	0
	Combined exposures	-	0
	Subtotal	-	0
JUne 87	Exposure SE & SU	-	0
	Exposure & Freeze-thaw	-	0
	Exposure & moisture shock	-	0
	Freeze-thaw	-	0
	Harkort testing	-	0
	Subtotal	-	0

July 87	Exposure SE & SU	no charge	0
	Exposure & freeze-thaw	-	0
	Exposure & moisture shock	-	0
	Freezing & thawing	-	0
	Subtotal	-	0
Ausugt 87	Combined exposure	-	0
	Testing	-	0
	Subtotal	-	0
September 87	Final report	-	0
October 87	Final report	-	0
12 October 87	GRAND TOTAL	8.23059	8.23059

APPENDIX B

Supply and Services Canada | Approvisionnements et Services Canada

OSS-MAS 9143-2 (4/81)

CONTRACT PLAN AND REPORT FORM – FORMULE DE PROJET DE CONTRAT ET DE RAPPORT

CONTRACT TITLE – TITRE DU CONTRAT

CONTRACTOR – ENTREPRENEUR

FILE NO. – N° DU DOSSIER	SERIAL NO. – N° DE SÉRIE
03SQ.23440-4-9156	OSQ84-00391

TASK DESCRIPTION – DESCRIPTION DE LA TÂCHE	TASK DURATION IN MONTHS – DURÉE DE LA TÂCHE EN MOIS												TASK COST – COÛT DE LA TÂCHE		
	1 OCT 86	2 NV	3 DE	4 JA87	5 FE	6 MR	7 AL	8 MY	9 JE	10 JL	11 AU	12 SE	PLANNED PRÉVU À L'ORIGINE	ACTUAL PRÉCÉDEMMENT	E.T.C. À VENIR
Procurement													0.78	1.12	0
Fabrication													2.25	5.745	0
Exposure SE & SU													0.59	1.366	0
Exposure Freeze-thaw													0.29	0	0
Exposure moist shock													0.28	0	0
Combined exposure													0.56	0	0
Harkort testing													0.60	0	0
Moisture shock													0.60	0	0
Freezing and thaw													0.60	0	0
Testing													0.40	0	0
Report													1.28	0	0
PLANNED COST BY MONTH – COÛT PRÉVU POUR CHAQUE MOIS	1.9	1.7	1.45	0.9	0.8	1.48	0	0	0	0	0	0	PLAN 8.23		
ACCV. PRÉCÉD. / E.T.C. BY MONTH – PRÉVISION POUR CH. MOIS	0	0	0	0	0	1.635	6.596	0	0	0	0	0		ACTUAL COÛTS RÉELS 8.231	E.T.C. À VENIR 0

APPENDIX C

Technical conclusions

CONCLUSIONS

1. Retention

1.1 The parameters that most influenced the retention (loss of solids in the white water) are the same for the products of both slags. These are, in decreasing order of importance:

- fibre length,
- pressing, and
- fly ash content.

2. Flexural resistance prior to exposure

2.1 In general, the Hamilton slag products cured in a steam box yielded adjusted flexural moduli of rupture that averaged 6.3% higher than those of the Algoma slag products cured by immersion. However, the Algoma slag products gave adjusted moduli of 5.4% higher on average than those of the type 50 cement products. These differences are not significant.

2.2 When the products of both slags were compared on the same basis (curing in saturated air) the flexural strengths were not significantly different from each other, nor from those of the type 50 cement products.

3. Exposure to aggressive waters

3.1 Resistance to visible deterioration caused by exposure to aggressive waters.

3.1.1 The Algoma slag products exposed to sea water were unscathed after exposure in 3 out of 4 cases while those of type 50 cement were unchanged in only 1 out of 4 cases.

3.1.2 The Algoma slag products exposed to sulfated water were unscathed in every case whereas the type 50 cement products were unaffected in only 1 out of 4 cases.

3.1.3 It was concluded that the Algoma slag products were more resistant to visible deterioration caused by exposure to aggressive waters.

3.2 Flexural resistance after exposure to aggressive waters

3.2.1 When only the saturated air cured products of both slags were compared the adjusted flexural moduli of rupture of Algoma slag products averaged 3% higher than those of the type 50 cement products while the Hamilton slag products averaged 14% higher.

3.2.2 When the moduli of the Algoma slag products cured by immersion

are compared against those of the Hamilton slag products cured in a steam box, the Algoma moduli averaged 6% higher than those of the type 50 cement while the Algoma slag products averaged 20% higher.

3.2.2.1 If no account is taken of the differences in curing then the Hamilton moduli average 7% higher than the Algoma moduli.

3.2.3 Since the differences in moduli before exposure to either of the aggressive waters were not significant, it is concluded that the Hamilton slag products have been shown to be more resistant to the loss of moduli caused by exposure to either aggressive water.

3.2.4 If only the results obtained after exposure to sea water are considered the Algoma moduli average 15% lower than those of the type 50 cement products while the Hamilton moduli average 12% lower.

3.2.5 If only the results obtained after exposure to sulfated water are considered the Algoma moduli average 35% higher than those of the type 50 cement products while the Hamilton moduli average 43% higher.

3.2.6 It is concluded that for exposure to sea water, the type 50 cement products are superior in resistance to the products of either slag, and that the Algoma slag is the least resistant binder.

3.2.6.1 For exposure to sulfated water, the products of either slag are more resistant than type 50 cement products, and Hamilton slag is the best binder.

3.2.7 The parameters that had the greatest influence on the moduli after exposure to the aggressive waters were fibre length and fibre content.

3.2.8 If it is the loss in moduli caused by exposure to the aggressive waters that is considered, then the parameters that had the greatest influence were pressing and the type of aggressive water.

4. Exposure to aggressive waters followed by freezing and thawing

4.1 Resistance to visible deterioration caused by exposure aggressive waters followed by freezing and thawing.

4.1.1 The exposure to sea water caused a slight to moderate spalling in every case for the type 50 cement products while those of Algoma slag suffered only a slight spalling in half the cases.

4.1.2 The exposure to sulfated water caused a slight spalling in 1 out of 4 cases for the type 50 cement products while none of the Algoma slag products suffered any visible damage.

4.1.3 It was concluded that the Algoma slag binder yielded products

that were more resistant to the visible deterioration caused by exposure to the aggressive waters than the type 50 cement binder.

4.2 Flexural strength after exposure to aggressive waters followed by freezing and thawing.

4.2.1 For the products exposed to sea water followed by freezing and thawing the adjusted flexural moduli of rupture of the Algoma slag products averaged 16% higher than those of the type 50 cement.

4.2.2 For the products exposed to sulfated water followed by freezing and thawing, the moduli of the Algoma slag products averaged 28% higher than those of the type 50 cement products.

4.2.3 If results after exposure to either type of aggressive water are combined, the moduli of the Algoma slag products average 23% higher than those of the type 50 cement products.

4.2.4 The parameters that most strongly influenced the moduli after exposure to the aggressive waters followed by freezing and thawing were the following in decreasing order of importance:

- fibre length,
- fibre content,
- silica fume content,
- type of curing, and
- type of aggressive water.

The insignificant parameters were:

- fly ash content,
- binder type,
- degree of fiberization, and
- dispersant content.

4.3 Change in flexural strength caused by exposure to aggressive waters followed by freezing and thawing.

4.3.1 When the decrease in moduli is considered, as opposed to the level of moduli, after exposure to the aggressive waters followed by freezing and thawing then the parameters that had the most influence on the decrease in moduli are the following in order of decreasing importance:

- type of aggressive water,
- binder type,
- fibre length, and
- fly ash content.

The insignificant parameters were:

- pressing,
- fibre content,
- air entraining agent content, and
- curing mode

4.3.2 It is interesting to note that the parameters do not have the same influence upon the level of the moduli that they have upon the change in moduli after exposure to the aggressive waters followed by freezing and thawing.

5. Exposure to aggressive waters followed by moisture shock exposure

5.1 Resistance to visible deterioration caused by exposure to the aggressive waters followed by moisture shock exposure

5.1.1 The exposures to sea water caused a slight to moderate spalling in every case with the type 50 cement products while the Algoma slag products only suffered visible deterioration (incipient delamination) in 1 out of 4 cases.

5.1.2 The exposures to sulfated water caused a slight spalling or delamination for half the type 50 cement products while the Algoma slag products did not resist as well since they all suffered from incipient delamination or moderate spalling.

5.1.3 It was concluded that the Algoma slag products are more resistant to exposure to sea water followed by moisture shock exposure than the type 50 cement products while the opposite is true in the case of the sulfated water.

5.2 Flexural strength after exposure to aggressive waters followed by moisture shock exposure.

5.2.1 For the products exposed to sea water followed by moisture shock exposure, the adjusted flexural moduli of rupture of the Algoma slag products averaged 20% higher than those of the type 50 cement.

5.2.2 For products exposed to sulfated water followed by moisture shock exposure the moduli of the Algoma slag products averaged 40% higher than those of the type 50 cement.

5.2.3 If the results of either type of aggressive water are combined then the moduli of the Algoma slag products average 30% higher than those of the type 50 cement.

5.2.4 It is concluded that the Algoma slag binder yields products that are superior to those of type 50 cement after exposure to aggressive waters followed by moisture shock exposure.

5.2.5 The parameters that most influenced the level of moduli after exposure to the aggressive waters followed by moisture shock exposure were the following in decreasing order of importance:

- fibre length,
- fibre content,
- silica fume content, and
- curing mode.

The insignificant parameters were:

- air entraining agent content,
- degree of fiberization,
- fly ash content, and
- superplasticizer content.

5.3 Change in flexural strength caused by exposure to aggressive waters followed by moisture shock exposure.

5.3.1 If the reduction in moduli, as opposed to the level of moduli, after exposure to aggressive waters followed by moisture shock exposure is considered, then the parameters that most influenced the decrease in moduli are the following in decreasing order of importance:

- pressing,
- fly ash content,
- fibre content,
- type of aggressive water, and
- dispersant content.

The insignificant parameters were:

- degree of fiberization,
- fibre length,
- air entraining agent content, and
- curing mode.

5.3.2 It is noteworthy that the parameters in general did not have the same influence on the level of moduli as on the decrease in moduli.

6. Exposure to freezing and thawing alone

6.1 Resistance to visible deterioration caused by only freezing and thawing exposure.

6.1.1 The Algoma slag products were unaffected in 6 out of 8 cases while the type 50 cement products were altered in half the cases.

6.1.2 It was concluded that the Algoma slag products were more resistant to visible deterioration caused by exposure consisting of only

freezing and thawing than the type 50 cement products.

6.2 Flexural strength after exposure consisting of only freezing and thawing.

6.2.1 The adjusted flexural moduli of rupture for the Algoma slag products averaged 29% higher than those of the type 50 cement products after exposure consisting of only freezing and thawing.

6.2.2 The parameters that most influenced the level of moduli after exposure consisting of only freezing and thawing were the following in order of decreasing importance:

- fibre length,
- fibre content,
- silica fume content,
- curing mode,
- fly ash content, and
- pressing.

The insignificant parameters were:

- superplasticizer content,
- dispersant content,
- air entraining agent content, and
- degree of fiberization.

6.2.3 There is no correlation between the parameters that most influenced the resistance against exposure consisting of only freezing and thawing for the Algoma slag products compared against those of the Hamilton slag.

6.3 Decrease in flexural strength caused by exposure consisting of only freezing and thawing.

6.3.1 If the reduction in moduli, as opposed to the level of moduli, after exposure consisting of only freezing and thawing is considered, then the parameters that most influenced the reduction in moduli are the following in decreasing order of importance:

- curing mode,
- air entraining agent content,
- pressing, and
- fibre content.

The insignificant parameters were:

- degree of fiberization,
- fibre length,
- binder type, and
- dispersant content.

6.3.2 It is interesting to note that it is frequently the same parameters that had the most influence upon either the level of moduli or the reduction in moduli after exposure consisting of only freezing and thawing.

6.3.3 There was no correlation observed between the parameters that most influenced the resistance to exposure consisting of only freezing and thawing for the Algoma slag products compared with those of the Hamilton slag.

7. Generalized resistance to all types of exposures

7.1 The normalized averages of reduction in moduli associated with the various types of accelerated weathering exposures are as follows:

NO.	EXPOSURE TYPE	PERCENT REDUCTION IN MODULI (normalized)	STANDARD DEVIATION
1	aggressive waters	25	12
2	aggressive waters followed by freezing and thawing	30	11
3	aggressive waters followed by moisture shock exposure	20	13
4	Freezing and thawing only	34	4

These results indicate that exposure 4 (freezing and thawing only) offers more discrimination (a greater reduction in moduli) and the best precision (lowest standard deviation).

7.2 It should be noted that the reduction in moduli caused by the various modes of accelerated weathering exposure were most influenced for the products of both slags by the following parameters in decreasing order of importance:

- fibre length,
- fibre content, and
- superplasticizer content.

The silica fume content and the mode of curing had an important influence on only the Algoma slag products.

8. Harkort trials

8.1 The products that gave the best resistance were coded 502, 609 and 806 and these include one type 50 cement and two Algoma slag products.

However, all of the latter were pressed products and free of air entraining agents. Two of the Algoma slag products showed incipient spalling but none showed any actual spalling whereas half of the type 50 cement products showed incipient spalling including 3 out of 8 that were actually spalled.

8.2 It is concluded that the Algoma slag products showed superior resistance to the Harkort test that combines very severe temperature and moisture shocks.

9. Density

9.1 Density prior to exposure

9.1.1 When the results for pressed and unpressed products are combined the Algoma slag products averaged 6.7% less dense than the type 50 cement products while the Hamilton slag products average 6.4% less. The Algoma slag products averaged 2% less dense than those of Hamilton slag before exposure.

9.1.2 If only the pressed products are considered, the Algoma slag products averaged 4.1% less dense than those of type 50 cement while those of Hamilton slag averaged 6% less. The Algoma slag products were of the same density as those of Hamilton slag within one percent, prior to exposure.

9.1.3 If only the unpressed products are considered the Algoma slag products averaged 10% less dense then those of type 50 cement while those of Hamilton slag averaged 6.9% less. The Algoma slag products averaged 5.7% less dense than those of Hamilton slag before exposure.

9.1.4 The parameters that most influenced the density of the products of both slags, including pressed and unpressed products, prior to exposure were the following in decreasing order of importance:

- pressing,
- fibre length,
- fly ash content,
- fibre content,
- binder type, and
- silica fume content.

The insignificant parameters were:

- degree of fiberization,
- superplasticizer content,
- curing mode,
- air entraining agent content, and
- dispersant content.

9.2 Density after exposure to aggressive waters

9.2.1 When the pressed and unpressed products are taken together, the Algoma slag products average 5.8% less dense than those of type 50 cement while those of Hamilton slag average 6.5% less. The Algoma slag products average 6.9% less dense than those of Hamilton slag after exposure to the aggressive waters.

9.2.2 When only the pressed products are considered, the Algoma slag products averaged 3.5% less dense than those of type 50 cement while those of Hamilton slag averaged 6.8% less. The pressed Algoma and Hamilton slag products were nearly equal in density after exposure to the aggressive waters.

9.2.3 When only the unpressed products are considered, the Algoma slag products averaged 8.6% less dense than those of type 50 cement while those of Hamilton slag averaged 5.7% less after exposure to the aggressive waters. The unpressed Algoma slag products averaged 6.2% less dense than those of Hamilton slag after exposure to the aggressive waters.

9.2.4 After exposure to sea water, the Algoma slag products had the same density as those of type 50 cement while those of Hamilton slag averaged 4% less. The densities of the products of both slags were equal after exposure to sea water.

9.2.5 After exposure to sulfated water the Algoma slag products averaged 10.6% less dense than those of type 50 cement while those of Hamilton slag averaged 17% less. The Algoma slag products averaged 5.1% more dense than those of Hamilton slag after exposure to sulfated water.

9.2.6 The parameters that most influenced the density after exposure to the aggressive waters were the following in decreasing order of importance:

- pressing,
- fibre length,
- fly ash content, and
- fibre content.

These parameters are the same ones that most influenced the density before exposure.

9.3 Change in density caused by exposure to the aggressive waters.

9.3.1 If the change in density is considred, as opposed to the level of density, after exposure to the aggressive waters, no correlation may be observed between the parameters that influenced the product density change after exposure to the aggressive waters.

10. Porosity

10.1 Porosity prior to exposure

10.1.1 The Algoma slag products prior to exposure averaged 16.3% higher porosity than those of type 50 cement while those of Hamilton slag averaged 19.5% higher. The Algoma slag products averaged 66.4% higher porosity than those of Hamilton slag prior to exposure and this constitutes an important difference. In view of this fact, it could have been expected that the Hamilton slag products should have shown much superior resistance to exposure to the various types of accelerated weathering but this did not manifest itself in the flexural strength results obtained after the various exposures.

10.1.2 When only the pressed products are considered the Algoma slag products averaged 42% higher porosity than those of type 50 cement while those of Hamilton slag averaged 20% higher. The porosities of the pressed products of both slags were equal, and they averaged 19.3% higher than those of type 50 cement before exposure.

10.1.3 When only the unpressed products are considered the Algoma slag products averaged 17% higher porosity than those of type 50 cement while those of Hamilton slag averaged 11% higher. The non pressed Algoma slag products averaged 22% higher porosity than those of Hamilton slag prior to exposure.

10.1.4 The parameters that most influenced porosity prior to exposure were the following in decreasing order of importance:

- pressing,
- fibre length,
- fly ash content, and
- fibre content.

The insignificant parameters were:

- degree of fiberization,
- air entraining agent content,
- superplasticizer content, and
- dispersant content.

10.2 Porosity after exposure to the aggressive waters

10.2.1 After exposure to the aggressive waters, the Algoma slag products averaged 30% higher porosity than those of type 50 cement while those of Hamilton slag averaged 11% higher. The Algoma slag products averaged 47% higher porosity than those of Hamilton slag.

10.2. When only the pressed products are considered, the Algoma slag products averaged 123% higher porosity than those of type 50 cement

while those of Hamilton slag averaged 144% higher. The pressed Algoma slag products averaged 13% lower porosity than those of Hamilton slag after exposure to the aggressive waters.

10.2.3 When only the unpressed products are considered the Algoma slag products averaged 29% higher porosity than those of type 50 cement while those of Hamilton slag averaged 12% higher. The unpressed Algoma slag products averaged 25% higher porosity than those of Hamilton slag after exposure to the aggressive waters.

10.2.4 When only the products exposed to sea water are considered the Algoma slag products averaged 6% less porous than those of type 50 cement while those of Hamilton slag averaged 17% higher. The Algoma slag products averaged 12% less porous than those of Hamilton slag exposed to sea water.

10.2.5 When only the products exposed to sulfated water are considered the Algoma slag products averaged 43% higher porosity than those of type 50 cement while those of Hamilton slag averaged 50% higher. The Algoma slag products averaged 6.6% higher porosity than those of Hamilton slag exposed to sulfated water.

10.2.6 The parameters that most influenced the porosity after exposure to the aggressive waters were the following in order of decreasing importance:

- pressing,
- fibre length,
- fly ash content, and
- fibre content.

The insignificant parameters were:

- degree of fiberization,
- air entraining content,
- curing mode,
- silica fume content, and
- superplasticizer content.

10.2.7 It is interesting to note that most of these parameters had the same influence on the porosities prior to exposure to the aggressive waters.

10.3 Change in porosity caused by exposure to the aggressive waters

10.3.1 If the change in porosity, as opposed to the level of porosity after exposure to the aggressive waters is considered, no correlation was observed between the parameters that most influenced the Algoma study and those that most influenced the Hamilton study.

10.3.2 If all the products (pressed and unpressed) exposed to either aggressive water are considered the increase in the absolute average porosity as well as the percentage porosity increase were slightly higher for the Algoma study than for the Hamilton study.

10.3.3 The products of both slags underwent porosity reductions of 34% caused by exposure to the aggressive waters. The absolute reduction in porosity of the Algoma slag products averaged 24% less than those of Hamilton slag.

10.3.4 The parameters that most influenced the reduction in porosity caused by exposure to the aggressive waters were the following in decreasing order of importance:

- fibre length,
- pressing, and
- type of aggressive water.

The insignificant parameters were:

- air entraining agent content,
- dispersant content,
- degree of fiberization, and
- superplasticizer content.

These parameters frequently have the same influences on the level of porosity as well as the change in porosity after exposure to the aggressive waters.

MC/pg